

PB-239 631

CRITERIA FOR REGIONAL SOLID WASTE MANAGEMENT PLANNING

REGIONAL SCIENCE RESEARCH INSTITUTE

PREPARED FOR
NATIONAL ENVIRONMENTAL RESEARCH CENTER

DECEMBER 1974

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-670/5-74-006	2.	3. PB 239 631
4. TITLE AND SUBTITLE CRITERIA FOR REGIONAL SOLID WASTE MANAGEMENT PLANNING		5. REPORT DATE December 1974-Issuing Date
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Benjamin H. Stevens, Principal Investigator		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Regional Science Research Institute GPO Box 8776 Philadelphia, Pennsylvania 19101		10. PROGRAM ELEMENT NO. 1DA312;ROAP 24ABV;TASK 18
		11. CONTRACT/GRANT NO. EP-01030
12. SPONSORING AGENCY NAME AND ADDRESS National Environmental Research Center Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES Project Officer: Ronald J. Talley (513) 684-4484		
16. ABSTRACT This report consists of a collection of studies on selected aspects of the problem of regional solid waste management planning. The research efforts fall into three main subject areas: the economics of solid waste generation recycling, and disposal; the economic and social effects of landfills; and the issues involved in local intergovernmental cooperation for regional solid waste management. The individual studies are the following: "A Framework for Evaluating the Economic Effects of Regional Solid Waste Systems", "Production Functions for Solid Waste Disposal", "Solid Waste Generation Coefficients: Manufacturing Sectors", "Solid Waste Generation Coefficients: Non-Manufacturing Sectors", "Perceptions of Landfill Operations Held by Nearby Residents", and "Efforts at Intermunicipal Cooperation for Solid Waste Disposal: Why They Fail". The report also includes a summary of the studies.		
17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COGATI Field/Group
*Regional planning, *Refuse disposal, *Industrial wastes, *Refuse, Incinerators	*Solid Waste Management Planning	13B
18. DISTRIBUTION STATEMENT Release to public	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 338
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

CRITERIA FOR REGIONAL SOLID WASTE MANAGEMENT PLANNING

By

Benjamin H. Stevens, Principal Investigator
Regional Science Research Institute
Philadelphia, Pennsylvania 19101

Grant No. EP - 01030
Program Element No. 1DA312

Project Officer

Ronald J. Talley
Solid and Hazardous Waste Research Laboratory
National Environmental Research Center
Cincinnati, Ohio 45268

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

1a

REVIEW NOTICE

The National Environmental Research Center-Cincinnati has reviewed this report and approved its publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

To help provide the basis for improved solid waste management, this study presents analyses of selected aspects of the problem of regional solid waste management planning.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

TABLE OF CONTENTS

	<u>Page No.</u>
I. SUMMARY	1
Introduction	1
Economics of Solid Waste Generation, Recycling & Disposal	2
The Input-Output Framework	2
Solid Waste Generation Coefficients	4
Production Functions for Disposal Activities	7
Recycling	8
Economic & Social Effects of Landfills	10
Local Intergovernmental Cooperation for Solid Waste Disposal	13
Conclusions	17
II. FRAMEWORK FOR EVALUATING THE ECONOMIC EFFECTS OF REGIONAL SOLID WASTE SYSTEMS	18
Introduction	18
Formulation of the Model	21
Input-Output Analysis and Environmental Problems	21
Input-Output Formulation: Waste Generation and Disposal	23
Input-Output Formulation: Recycling	26
Properties of the Model	32
Induced Effects	32
The Economic Repercussions of Recycling	38
Constraints on Final Demand	45
Price Effects	49
Application of the Model	56
Refinements for Practical Applications	56
Uses of the Model	59
Limitations of the Model	61
Data Requirements	62
Summary	64
III. SOLID WASTE GENERATION COEFFICIENTS: MANUFACTURING SECTORS	71
Introduction	71
Description of Coefficients	75
Data	80
Sources of Data	81
Sample Coverage	85

Some Comments on the Collection of Information on Solid Waste	89
Cooperation	89
Procedures	91
Analysis	94
Level of Industrial Aggregation	94
Variance	102
Comparison with Previous Studies	105
Summary	114
Bibliography	115
Appendix A A. Questionnaire and Introductory Letters: Supplementary Survey	118
- B. Questionnaire: Pennsylvania Industrial Solid Waste Inventory	124
- C. Questionnaire: Pennsylvania Air Management Inventory ...	127
- D. Volume to Weight Conversion Factors	129
- E. Calculation Procedures	132
- F. Summary of Philadelphia and Texas Solid Waste Generation Coefficients	138
- G. Solid Waste Generation Coefficients	156
IV. SOLID WASTE GENERATION COEFFICIENTS: NON-MANUFACTURING SECTORS	167
Data Sources	185
Bibliography	187
V. PRODUCTION FUNCTIONS FOR SOLID WASTE DISPOSAL	188
Introduction	188
Waste Disposal Activities	189
Data Sources	190
Collection and Transportation	192
Incineration	197
Landfill Costs	202
Transfer Station	203
Comparison of Disposal Costs in Large Cities	208
Reservations on the Use of the Production Functions	209
Summary	209
Bibliography	212

VI. PERCEPTIONS OF LANDFILL OPERATIONS HELD BY NEARBY RESIDENTS	213
Introduction	213
Choice of Sanitary Landfills to be Studied	214
Specific Operating Characteristics of Landfills	216
Household Interviews	220
Knowledge of Landfill	222
Existence of Landfill	222
Past and Future Use of Landfill Site	223
Sources of Information and Reasons Why Landfill was Located in Neighborhood	227
Attitudes Toward Landfills	230
Effect on Neighborhood	230
Specific Problems Perceived	234
Perception of Effects of Landfills	244
Overall Regression Analysis	251
Regression Analysis of Selected Factors	256
General Conclusions	259
Appendix - A. Operating Characteristics and Physical Characteristics of Landfills	262
- B. Tabulation of Responses: Knowledge of Landfill	267
- C. Tabulation of Responses: Attitudes Towards Landfill	269
- D. Personal Characteristics of Respondents	273
- E. Notes on Each of the Landfills	276
- F. Questionnaire	279
VII. EFFORTS AT INTERMUNICIPAL COOPERATION FOR SOLID WASTE DISPOSAL: WHY THEY FAIL	284
Introduction	284
Political Organization	286
In Metropolitan Areas	286
Organization for the Provision of Solid Waste Disposal	289
Case Studies in Cooperation for Waste Disposal	292

I. SUMMARY

Introduction

This report is a summary and evaluation of the solid waste research performed by the Regional Science Research Institute under Grant No. R-800672 from the Environmental Protection Agency. Because the grant was terminated after the first budget year, this is not a full-scale final report of the usual type. Rather, it serves as overall introduction and general conclusions for the individual studies, each of which are reported in separate chapters.

This report, therefore, is brief. Its purpose is to set a context for the several research efforts. The original purpose of the grant was to study selected aspects of the problem of regional solid waste management planning. The research efforts fell into three main subject areas: the economics of solid waste generation, recycling, and disposal, the economic and social effects of landfills, and the issues involved in local intergovernmental cooperation for regional solid waste management. These three main areas, and the research results obtained for each, are discussed below. The individual presentations are followed by overall conclusions and evaluations, including suggestions for further study.

Economics of Solid Waste Generation, Recycling, and Disposal

The Input-Out Framework*. Input-output analysis is an appropriate model context for this effort, both because it organizes information in a logical and consistent framework, because it permits the evaluation of the solid waste loads generated directly and indirectly through the interaction of economic units in the region, and because it permits the analysis of possible recycling activities by expressly considering their secondary effects on employment and output in other economic activities. The value of the input-output scheme is that it can measure the solid waste impacts of projected economic changes. A particular rise in, say, steel industry employment will generate a direct increase in solid waste from that industry but also indirect increases from expansion in the output and employment of all industries which supply the steel industry, in the industries which supply them, and so forth. In other words, the ability of input-output to generate both the direct and indirect effects of a particular change in output and employment also permits it to generate direct and indirect, and hence total, outputs for each type of solid waste.

*Gene Steiker, "A Framework for Evaluating the Economic Effects of Regional Solid Waste Systems", Regional Science Research Institute Discussion Paper Series: No. 72, April 1974.

Incorporation of solid waste into the input-output model requires some unorthodox conventions and definitions. First, solid waste is a residual by-product which requires inputs of waste disposal services, rather than a primary product which is produced in response to changes in demand. Furthermore, it has only a negative "value," in terms of its disposal costs, except to the industries which deal in such materials, and those scrap materials, such as paper and metals, which do have a positive economic value have tended to exhibit wide fluctuations in market price. For example, scrap steel quadrupled in price between April 1973 and April 1974.

Therefore, it is better not to put solid waste coefficients into the usual units of cents worth per dollar output of the producing industry. Rather, waste material is kept in its "physical" units in order to trace its flow through the system and to avoid placing fixed monetary values (or costs) on it. Furthermore, recycling and salvage are activities which reduce the required level of waste disposal services on waste materials whose quantities are determined solely by the industries which produce them. Thus, an exogenous demand for scrap steel by the steel industry should not, in the model, generate increased waste output of industries which produce scrap as a by-product.

The adaptations of the model necessary to deal with these and related problems are discussed in the aforementioned paper. Limitations of time and funds prevented most of the adaptations from actually being carried out on a working model. However, the framework is complete enough to allow the practical adaptation and application of the model once a full set of data is available. To this end, further research on the supply and demand for waste materials has already been proposed.*

Solid Waste Generation Coefficients.** A major contribution of the study has been the compilation of solid waste generation coefficients. Data for this purpose were compiled both from previous industrial surveys in Pennsylvania and other states and from original data collection by interviews of Philadelphia Area firms. The major effort was concentrated on manufacturing firms, and data were collected for fourteen types of materials which are typical of manufacturing waste. The existing and newly-collected data were assembled at the 3 and 4-digit SIC level to match the detailed industrial

*"Supply and Demand for Scrap: An Hypothesis on Market Characteristics and a Proposal for Further Research," Regional Science Research Institute, April 1974.

**Gene Steiker, "Solid Waste Generation Coefficients: Manufacturing Sectors," Regional Science Research Institute Discussion Paper Series: No. 70, December 1973.

breakdown of the existing Philadelphia Region Input-Output Model.

A "best" output coefficient was then calculated for each of the fourteen waste materials in terms of tons of material per employee per year for each of the manufacturing industries; some of these coefficients are, of course, zero. With the set of coefficients and projected levels of employment for each industry, the tonnage of each waste material can easily be calculated.

A next step, if the research were to continue, would be to transform these coefficients into tons of each material per dollar output of producing industry per year. This would eliminate the intermediate calculation of employment and provide physical quantities of wastes directly from the input-output calculation.

The coefficients obtained in this study are not, of course, definitive. They are probably the best set now available, in part because they are the distillation of several sets of data including original interview material. Nevertheless, there are difficult problems of definition and measurement in the assembly of this type of data. Many of these difficulties are discussed in the aforementioned paper.

Even less definitive are the coefficients for non-manufacturing activities. One reason is that these received less attention in the study. This was partly because it was felt that the solid waste per employee was on average less for such activities, more homogeneous in its composition (fewer major materials represented) and, in the case of households, much more information was already available.

The coefficients for non-manufacturing sectors of the economy were estimated using all available secondary sources and therefore, can be considered to be a compilation of the best knowledge in the field.* Given time and budget limitations it was not considered desirable to carry out a direct survey of non-manufacturing sectors. The most significant sector is contract construction, which probably deserves further study because its total waste output per employee per year is over three times that of the average of all manufacturing activities.

*Thomas Kontuly, "Solid Waste Generation Coefficients: Non-Manufacturing Sectors," Regional Science Research Institute Working Paper, April 1974.

Production Functions for Disposal Activities*

Waste disposal activities were studied for the purpose of developing labor and material input coefficients for them. An accurate set of such coefficients is essential to the eventual integration of disposal into the input-output model. The data for this part of the study were assembled from the budgets and reports of municipalities in the Philadelphia SMSA. Problems of non-comparability in accounting systems, and the fact that many municipalities contract for their waste disposal with private firms or other municipalities, made this difficult.

It was decided to develop separate production functions for various components in the disposal process because of the variations among areas in methods of disposal, lengths of hauls, etc. Thus collection, transportation, transfer, incineration, and landfill all have separate sets of coefficients. This would allow, of course, the assembly of an overall set of input coefficients for any particular combination of levels of intensity of for these activities, as well as disaggregation specific to disposal processes employed in different sub-regions.

*Thomas Kontuly, "Production Functions for Solid Waste Disposal," Regional Science Research Institute Working Paper, April 1974.

Disposal costs for the Philadelphia SMSA turned out to be comparable, in general, to the published figures for other SMSAs. Nevertheless, rapid changes in technology, changes in the level of recycling, and changes in the solid waste mix could all effect the operating costs figures and, hence, the input coefficients.

Recycling

As already noted, the conceptual problems of integrating recycling activities into the input-output framework have been dealt with, but the empirical problems have not. One problem, of course, is that rapid technological and price changes have made certain types of recycling plausible which seemed, until recently, economically unfeasible.

Because of the recent rapid rise in prices of raw materials, the potential economic effects of recycling may be much more significant than earlier thought. Since recycling reduces the amount of disposal needed and raises the value of byproducts, one should expect that a major recycling effort would cause major substitutions among products and processes. These substitutions would have, in turn, impacts on certain affected industries in a region and on the economics of other regions which have been the suppliers of virgin materials.

It would seem useful, therefore, to scrutinize carefully the integrated solid waste plan of, for example, the State of Connecticut. This plan has a large component of recycling, so the Connecticut experience could provide data on both the production functions of recycling activities and their substitution effects.

Economic and Social Effects of Landfills*

This part of the research was focused on the effects of landfill sites on surrounding neighborhoods. A random sample of residents living near each of a selected sample of eight landfill sites were interviewed for their reactions to having what is generally considered an objectionable land use in their neighborhood.

The responses to the 844 interviews were somewhat surprising. Overall, residents seem to find landfills a negative influence but less of a nuisance than had been expected. Only where there were serious problems of smell, smoke, dust, pests and/or local truck traffic did most residents appear to have a strongly negative reaction to the landfill. A substantial percentage of persons had, in fact, moved into their homes after the landfill was established. Most felt that the landfill operation had minimal effect on the value of their property.

It is interesting to note, however, that many reactions were based on predispositions and preconceptions rather than objective characteristics of the landfills. In some cases even well-run

*Robert E. Coughlin, Harriet Newburger, and Cary Seigner, "Perceptions of Landfill Operations Held by Nearby Residents," Regional Science Research Institute Discussion Paper Series: No. 65, August 1973.

landfills were considered objectionable, especially by new arrivals among residential population. Many listed "just the fact that it is there" as a major source of their objections. Yet older residents did not seem so bothered.

If this is true, the problem of establishing new landfills will continue to be tougher than keeping them in successful and locally-acceptable operation once they are established. This problem is discussed further below.

In passing, it should be noted that a quick and otherwise unreported study was done of land values around one of the sites. This site, in Philadelphia proper, was chosen because the housing around it was relatively homogeneous, the lots mostly the same size, and good property value data easily available. This meant that any significant variations in assessed or market values might be attributed to the landfill.

But the expected depression of values for properties adjacent or close to the landfill was not large enough to be statistically significant. In fact, neither the land value data nor the interview results suggest that there is a "natural" neighborhood for a landfill. Rather, strength of effect does not appear to be closely correlated with distance from the landfill;

negative reactions can come from quite far away, especially along truck routes. This wide-ranging nature of perceived effects is likely to exacerbate the problem of obtaining and establishing new landfill sites.

Local Intergovernmental Cooperation for Solid Waste Disposal*

A regional solid waste management system should hopefully take advantage of economies of scale by concentrating various parts of the processing and disposal activities in a few locations. Especially in the less densely-populated areas of the region it is unlikely to be efficient for each municipality to have its own disposal system. This may not be as important as was thought at the outset of the research since it appears that the economies of cooperation, at least in incineration and landfill operation, are less dramatic than anticipated.

Nevertheless, more sophisticated systems of waste separation and major development of recycling will probably require concentration in a few centers as has been proposed for the Connecticut Plan. And in any case, it is not likely to be economically efficient to use valuable centrally-located land for ultimate disposal unless transportation costs become significantly higher relative to other costs. Thus inter-municipal cooperation will probably be necessary to most successful and efficient regional plans.

* Jane Gilbert, "Efforts at Intermunicipal Cooperation for Solid Waste Disposal: Why They Fail," Regional Science Research Institute Discussion Paper Series: No. 68, October 1973.

The case studies of a small sample of four attempts at intermunicipal cooperation in the Philadelphia Region were not especially encouraging. Although citizen protest against landfill sites was an important factor in some of the failures of these multimunicipal plans, simple inability to communicate and negotiate intelligently seems to have made a major contribution to the relative lack of success. The most successful operation is on in which a dedicated individual provides strong leadership; in others, the rule seems to have been "death by committee."

The difficulty, of course, is that everyone is willing to cooperate if it doesn't cost him anything. In particular, no community wants to provide the location for the landfill, incinerator, or other facility. One suggested approach to dealing with this problem has been to propose a rotating system in which a series of short-term facilities would be located sequentially in each of the cooperating municipalities. Then, over a period of time, each town would absorb its share of the waste load. Aside from no town wanting to be first, or second, or anything but last in the sequence, this approach seems to be a potentially viable strategy. Unfortunately, even this equitable approach seems to work only in the short run, if at all.

Actually, however, there is an underlying socio-psychological problem inherent in waste disposal. Most groups are now willing, at least grudgingly, to accept their own waste as their own responsibility. But no one wants to be the dump for someone else's waste. The most exaggerated form of this reaction is probably the rejection by the hard-coal region of Pennsylvania of a plan to ship Philadelphia's waste by rail to be deposited in old mines. This would have reduced subsidence and acid mine drainage, rebuilt the landscape, and provided badly-needed employment.

The most basic problem, after all, is probably the typical problem of "externalities." By their nature, externalities are produced individually and absorbed jointly. If they are mutual external effects, social optimality often lies in cooperation if it can be achieved. But it is generally in the best interests of the individual, at the outset, to refuse to cooperate unless it is guaranteed that all others will also cooperate. Thus the potential political and fiscal costs of cooperation for a municipal government are larger than the expected benefits if indeed other municipalities also pursue their selfish best interests.

This is really an extended form of the "prisoner's dilemma" of formal game theory. It can be shown, through this extension,

that cooperation is unlikely, or unlikely to be successful, among coequal municipal partners in the provision of necessary but "undesirable" solid waste facilities. This suggests that the rules of the game may have to be changed in order to make inter-municipal cooperation more attractive to the participants. This might be done by increasing the benefits to cooperation through State or Federal subsidies, or forcing regional cooperation through legislative action at higher levels of government.

This may work for coequal municipalities. It will be much more difficult, politically, to solve the problem of center cities of SMSAs such as Philadelphia. New Jersey now bans the "importation" of solid waste from Pennsylvania; there is increasing pressure to cease dumping at sea; most of the City's land is too valuable for use as landfills; pollution controls make further development of incinerators increasingly costly; and Philadelphia's rejection by the hard coal area has been noted. Under such conditions, the full impetus for and financing of a solid waste system may have to come from the State, as in Connecticut.

Conclusions

The research summarized in this report and the papers referred to fulfilled the original expectations for the first budget year of the grant. The work is, of necessity, incomplete. But the results do provide basic material with which regional solid waste planning can proceed on a firmer footing.

Of the work yet to be done, the most important is probably the completion of the economic analysis. This should include the estimation of production functions for major recycling activities, analysis of the supply and demand for scrap materials, and the full integration of waste generation, recycling, and disposal into the input-output model.

Once this is done, tests can be run to determine the regional economic and fiscal effects of alternative approaches to the solution of solid waste problems. These approaches should include various systems of taxes and subsidies to encourage reuse and/or particular methods of collection, processing, and disposal. They may also include methods of encouraging intermunicipal cooperation for the purpose of concentrating facilities to the enhancement of economies of agglomeration and the minimization of the social costs inherent in the constraints on the size and location of solid waste facilities.

II. A FRAMEWORK FOR EVALUATING THE ECONOMIC EFFECTS OF REGIONAL SOLID WASTE SYSTEMS*

Introduction

Population growth, higher levels of consumption, technological changes, and alterations in consumption patterns such as the popularity of "disposable" products have resulted in the generation of increasingly larger amounts of solid waste. At the same time, greater concentration of population in urban areas and heightened concern over environmental quality have made waste disposal more difficult and expensive. Additional problems are associated with certain types of waste like plastics and synthetic materials, which are not amenable to re-use and difficult to dispose of without environmental damage.

The methods and institutional arrangements presently used for waste collection and disposal are generally considered inadequate (Council on Environmental Quality [1970]). A number of new ideas for waste disposal techniques and policies to deal with solid waste problems have been suggested, including disposal technologies like composting and pyrolysis, interregional cooperation in providing collection and disposal services, and the use of waste as fuel in producing energy. Recycling, in particular, is often proposed as a solution to waste disposal, resource depletion and environmental problems (Randers [1971]). Solid waste problems have only recently received attention, however, and little comprehensive planning has been done in the area so that

*Chapter II written by Gene Steiker.

Formulation of the Model

Input-Output Analysis and Environmental Problems. Several features of input-output analysis make it suitable for environmental economic studies. An input-output model describes the level of output in each sector of an economy in terms of corresponding levels of activity in other sectors and traces out the multiplier effects of individual industries through the economy¹. Outputs of waste or pollution byproducts are associated with almost every economic activity including household consumption (Ayres and Kneese [1969]). The generation of residuals and their disposal or abatement, if such a concept is realistic as in the case of solid waste, may be represented and analyzed in terms of technical relationships similar to those used to model the structural interdependence between conventional production and consumption activities.

Input-output is a general equilibrium approach that may be used to capture the indirect as well as direct interrelationships between various segments of the economic system and the environment. Important repercussions of a particular waste disposal system or recycling activity are unlikely to be apparent from examination of just the solid waste activity alone. For example, a recycling industry may stimulate other waste generating industries to such an extent through intermediate demands for inputs,

that it indirectly produces a great deal of refuse or air pollution. This may be true for paper recycling which requires large inputs of energy and would be an important consideration in evaluating the desirability of recycling that can only be assessed by regarding the activity as a part of the larger economic system.

It is possible to implement large input-output models that represent an economic system at a very detailed and disaggregated level² which allows analysis of interdependencies between activities that would otherwise be hidden. In addition, the technique provides flexibility in modelling regional economies and the capability of identifying intraregional spatial effects.

Problems associated with solid waste disposal are especially difficult in urban areas where large quantities of refuse are generated, landfill sites are scarce, and air pollution problems acute. Transporting the refuse any distance adds considerably to disposal costs. Large cities are also the most likely locations for recycling activities since urban regions have large supplies of waste in close proximity to industries that might serve as markets for recycled materials. Consequently, the discussion that follows will pertain to regional applications of input-output analysis.

The use of input-output techniques have been suggested for predicting air pollution, water pollution, and solid waste generation and also for evaluating the environmental effects of economic development objectives (Isard, et al. [1972]; Cumberland [1973]). A number of applications have been carried out empirically to the extent of predicting the amounts of air and water pollution as well as solid waste (Cumberland [1973]; Gouleke [1971]; Ayres, et al. [1971]; Hite and Laurent [1971]).

Less work has been done in evaluating the economic effects of disposal facilities and recycling sectors with the use of input-output methods. Ayres and Kneese [1969] have proposed a model based on a materials balance approach in which the total weight of residuals leaving the system must be equal to the sum of the weights of materials entering the system, according to the law of conservation of mass and energy. Aside from a number of theoretical problems (Noll and Trijonis [1971]; Converse [1971]) it is unlikely that such a model could be implemented empirically.

The input-output formulation suggested by Leontief [1970] is more promising from the viewpoint of application, and it is the basis for the model discussed in the following pages. Leontief integrates the generation of residual byproducts of production and their disposal into a model of the economic system.

However, no mention is made of recycling. Romanoff [1972] discusses the role of recycling sectors in a regional economy, but is not explicit about the method of incorporating recycling sectors in the input-output table.

The Leontief model, as will be shown, may be extended quite easily to include recycling activities and the modification leads to some interesting conclusions about the economic effects of recycling.

Input-Output Formulation: Waste Generation and Disposal

The structural matrix of an input-output system represents the technology of the economy. Each column of the matrix corresponds to the production function for a particular sector, the column entries showing the amount of products of the other sectors required to produce one unit of output in the industry designated by that column. The model that appears below defines an augmented structural matrix where the production function relationships between conventional economic sectors are represented (A_{11}), and where the production functions also include coefficients that account for the generation of waste (A_{21} and A_{22}). Additional columns are included for waste disposal activities (A_{12} and A_{22}).

$$(1) \quad \left[\begin{array}{c|c} I - A_{11} & -A_{12} \\ \hline -A_{21} & I - A_{22} \end{array} \right] \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \left[\begin{array}{c|c} I - A_{11} & -A_{12} \\ \hline -A_{21} & I - A_{22} \end{array} \right]^{-1} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

where: $A_{11} = [a_{ij}]$ = input of good i per unit output of sector j .

$A_{21} = [a_{gj}]$ = output of solid waste or pollutant g per unit output of sector j , equal to the amount of waste disposal required per unit output of sector j .

$A_{12} = [a_{ig}]$ = input of good i per unit of solid waste disposal by disposal sector g .

$A_{22} = [a_{gk}]$ = net output of waste or pollutant g per unit of disposal by disposal of sector g .

$X_1 = [x_i]$ = total output of good i .

$X_2 = [x_g]$ = total amount of waste g eliminated by the disposal sector.

$Y_1 = [Y_i]$ = final demand for good i .

$Y_2 = [Y_g]$ = exogenous demand for waste disposal (if $Y_g > 0$) or the amount of waste not requiring disposal (if $Y_g < 0$).

Waste produced as byproducts by the various economic sectors is represented by the elements below the dashed horizontal line in the system shown above. These waste generation coefficients indicate the quantity of solid waste or other effluents produced per unit output in each activity preferably measured in physical units. Expressing waste quantities in physical units avoids the

problem of determining arbitrary values for these byproducts.

Columns corresponding to the waste rows represent the production functions for the sectors that dispose of the residuals (the elements to the right of the vertical partition). Waste disposal is much like other economic activities in that inputs (materials, labor, transportation, services, etc.) are required to produce waste disposal services. The system is set up so that the disposal sector provides disposal services for all the waste generated. Including disposal as an endogenous sector in the table allows the model to capture the multiplier effects of this activity.³

If waste disposal or pollution abatement sectors are not included as endogenous to the table, A_{12} and A_{22} are null matrices and the system reduces to the conventional determination of total output in the various sectors with additional equations that show the total amount of each type of solid waste or pollution generated in the production process. This is the type of analysis done in the applications cited previously (Cumberland [1973]; Gouleke [1971]; Hite and Laurent [1971]).

Final demand for waste disposal services (Y_2) requires some comment. A positive value here would indicate exogenous demand for waste disposal services. Much of the solid waste generated

in Philadelphia is transported to landfills in New Jersey and the city of San Francisco ships its solid waste to a rural county in California by train. An exogenous demand for waste disposal services, therefore, is realistic for certain regions that might be studied.

Negative final demand for waste disposal services is also a possibility. This would be interpreted as waste delivered to households and not handled by the disposal sector. The community might export scrap or perhaps tolerate a certain amount of litter. The concept actually would have more application to forms of pollution other than solid waste where natural processes might have some limited capacity to absorb the effluent and therefore abatement would not be necessary for a certain amount of pollution.

Input-Output Formulation: Recycling

Recycling may be defined as the recovery of waste materials as inputs in producing usable products. Recycling activities absorb materials that would otherwise have to be disposed of as solid waste and therefore decrease the amount of waste disposal required by the system. This relationship between recycling and waste disposal may be represented in the input-output system by a negative coefficient at the appropriate position for the re-

cycling sector's production function in the solid waste row (A_{21}), indicating that less waste disposal is required for every unit of output produced by the recycling sector, due to the input of scrap material.

Consider the simple three-sector economy represented by the following structural matrix.

	Generation	Recycling	Disposal
(2) Waste Generation	a_{11}	a_{12}	a_{13}
Recycling	a_{21}	a_{22}	a_{23}
Waste Disposal	a_{31}	$-a_{32}$	a_{33}

Sector 1 uses a_{11} units of output from firms in the same industry and a_{21} units of products from sector 2 for each unit of output produced. These coefficients are normally measured in the value of inputs per dollar output. In addition, sector 1 generates solid waste and so it requires a_{31} units of waste disposal for every unit of output. Waste quantities would be expressed in physical units so that this coefficient might indicate that a_{31} tons (or some other measure of physical units such as cubic yards) of waste disposal services are necessary for every dollar of output in sector 1.

Sector 2 recycles. It uses a_{32} units of scrap material, again expressed in physical units of measurement, for every unit of output produced. Less waste disposal is required because sector 2 absorbs materials that would otherwise be solid waste and thus sector 2 has a negative intermediate demand for waste disposal services.

The third column represents the production function for the waste disposal sector which requires inputs from the other sectors in order to dispose of waste. Since waste disposal requirements are expressed in physical units, the output of the disposal sector must be measured in the number of physical units of solid waste that is processed. Therefore, the coefficients in the third column indicate that a_{13} and a_{23} dollars of output from sectors 1 and 2 respectively are required to produce one ton of waste disposal services. The coefficient in the waste row for the disposal sector (a_{33} , expressed in tons of waste per ton of waste disposal) may indicate that some waste is generated directly as the result of the disposal process.⁴

The balance equation formulation for this example, corresponding to the previous generalized discussion, is shown below.

$$(3) \quad \begin{bmatrix} 1 - a_{11} & -a_{12} & -a_{13} \\ -a_{21} & 1 - a_{22} & -a_{23} \\ -a_{31} & +a_{32} & 1 - a_{33} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

Writing out the balance equations for the system, notice that each row of the table and therefore the elements of each equation are expressed in comparable units of measurement so that the system may be manipulated like a conventional input-output table.

$$\begin{aligned} X_1 - a_{11}X_1 - a_{12}X_2 - a_{13}X_3 &= Y_1 \\ (4) \quad X_2 - a_{21}X_1 - a_{22}X_2 - a_{23}X_3 &= Y_2 \\ X_3 - a_{31}X_1 + a_{32}X_2 - a_{33}X_3 &= Y_3 \end{aligned}$$

The balance equations for the first two sectors are subject to the usual input-output interpretation; total output minus intermediate demand is equal to final demand for the sector's output expressed in dollar values. Rewriting the third equation:

$$(4a) \quad X_3 = (a_{31}X_1 + a_{33}X_3 + Y_3) - (a_{32}X_2)$$

The amount of waste disposal for the system is equal to the amount of waste generated ($a_{31}X_1 + a_{33}X_3$; i.e., the amount of waste per unit of output in each waste generating sector times the total output for the sectors), plus any exogenous demand for disposal

services (Y_3), minus the amount of scrap used by the recycling sector ($- a_{32}X_2$), all expressed in physical units.

Intuitively, the model may be thought of as allocating all the waste to a hypothetical central pool. Recycling activities draw scrap from the waste pool and the remainder is sent off for disposal. The form of the model has some implications for data collection on solid waste. One labor saving aspect is that although it is necessary to have waste generation information for various industries and data on inputs of scrap material by recycling sectors, it is necessary to know only which type of waste is being reused but not which sector's waste is recycled.

A second point is that data collected on waste generation by various sectors should include information on how much material is sold or given away as scrap as well as the amount of refuse requiring disposal. The issue is really one of defining solid waste. A firm's outputs might be differentiated into three categories: primary products, joint products, and byproducts. Although certain byproducts may be sold by the firm, they are not true joint products unless the firm will increase its output of the item in response to an increase in demand or price. Byproducts that are not sold or given away for reuse are solid waste.

While there are exceptions, most scrap materials are clearly byproducts. For example, paper converting industries such as box manufacturing firms generate clippings that are high quality scrap material and most large paper converters sell this byproduct. It is unrealistic to suggest, however, that these firms would generate more clippings if the demand for scrap paper increased. The firms possibly gain some revenue or at least save on waste disposal expenses by selling the scrap, but this is a secondary consideration. The scrap paper is a residual of producing their primary products.

Properties of the Model

Induced Effects

The distinction between byproducts and joint products is the motivation for the method suggested for handling recycling in the input-output model. If scrap material is regarded as joint product an intermediate demand for scrap would be represented in an input-output table as a sale from the waste generating sector to the sector using the scrap as an input. The coefficient in the waste generating industry's row and the waste using industry's column in the case of recycling (a_{12} in the example) would reflect both the value of the primary product and the waste byproduct sold to the sector that reuses the waste. This method leads to an unrealistic effect in the solution of the system. As the output of the recycling sector increases, the waste generating sector will be required to increase its output in order to supply scrap byproducts since, in the table, the scrap sales are indistinguishable from the sales of the primary product of the waste producing sector.

The formulation presented here avoids the inclusion of any unwanted intermediate demand effects due to the use of byproducts in a recycling industry. The sale of each sector's primary products to the recycling activity is separated from transactions

involving byproducts so that an increase in the output of the recycling industry will induce more production in the other sectors only because of requirements for their primary products as inputs. The amount of scrap material used as an input to the recycling industry has only the direct effect of reducing the amount of waste that must be disposed of by the disposal sector in much the same way that the generation of waste by another sector would increase the amount of waste disposal services required.

This may be demonstrated by working out the round-by-round requirements for the hypothetical three sector example. In round 1:⁵

$$(5) \quad \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & -a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} x_1^1 \\ x_2^1 \\ x_3^1 \end{bmatrix}$$

$$x_1^1 = a_{11}y_1 + a_{12}y_2 + a_{13}y_3$$

$$(5a) \quad x_2^1 = a_{21}y_1 + a_{22}y_2 + a_{23}y_3$$

$$x_3^1 = a_{31}y_1 - a_{32}y_2 + a_{33}y_3$$

No undesirable induced effect occurs in the first round. Demand for sector 2's output does induce increased output from sector 1, but only because sector 2 uses inputs of the primary product of sector 1 ($a_{12}Y_2$). The effect of sector 2 recycling is represented by a_{32} . In the first round the only effect the recycling has is to reduce the amount of waste disposal necessary ($-a_{32}Y_2$, in the third equation above) since this is the only place that the recycling coefficient appears. In later rounds, it will be seen that less output is required from the other sectors to supply inputs to the disposal sector than would be the case in the absence of recycling.

On the second round, the outputs necessary to produce the first round requirements are calculated.

$$(6) \quad \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & -a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1^1 \\ x_2^1 \\ x_3^1 \end{bmatrix} = \begin{bmatrix} x_1^2 \\ x_2^2 \\ x_3^2 \end{bmatrix}$$

$$(6a) \quad x_1^2 = (a_{11}^2 + a_{12}a_{21} + a_{13}a_{31})Y_1 + (a_{11}a_{12} + a_{12}a_{22} - a_{13}a_{32})Y_2 + (a_{11}a_{13} + a_{12}a_{23} + a_{13}a_{33})Y_3$$

$$x_2^2 = (a_{21}a_{11} + a_{22}a_{21} + a_{23}a_{31})Y_1 + (a_{21}a_{12} + a_{22}^2 - a_{23}a_{32})Y_2 + (a_{21}a_{13} + a_{22}a_{23} + a_{23}a_{33})Y_3$$

$$x_3^2 = (a_{31}a_{11} - a_{32}a_{21} + a_{33}a_{31})Y_1 + (a_{31}a_{12} - a_{32}a_{22} - a_{33}a_{32})Y_2 + (a_{31}a_{13} - a_{32}a_{23} + a_{33}^2)Y_3$$

Recycling does effect the output of sectors 1 and 2 on the second round. The first equation shows the second-round output requirements for sector 1 (x_1^2). The recycling coefficient (a_{32}) appears in this equation, but notice that it appears in the same term with the coefficient indicating the input of sector 1 primary output to the disposal sector (a_{13}). As demand for sector 2 output (Y_2) increases, the term indicates that less output is required from sector 1 because of recycling reducing the amount of waste disposal necessary and thus the disposal sector requires fewer inputs from sector 1. This term is the result of final demand for sector 2 causing more recycling in the first-round, $(-a_{32}Y_2)$ in the equation for x_3^1 in (5a). This reduces the level of waste disposal (x_3^1), and the second-round requirements for first-round waste disposal are calculated by multiplying x_3^1 by the first element of the third, or disposal, column of the structural matrix (a_{13}) in (6). Similar remarks apply to x_2^2 . The only place where a_{32} appears without an element of the disposal

column is in the equation showing second-round effects on the waste disposal activity.

Furthermore, no undesirable induced effects will occur in any further rounds. A term in which a_{32} appears without an element from the third column or the disposal sector would indicate such an induced effect. Imagine computing the third round of requirements. X_1^2 would be multiplied by each element in the first column of the structural matrix, as in (6). Since a_{32} appears with an element of the waste column in X_1^2 and a_{32} does not appear in the first column, the results of these operations will never have a term where a_{32} appears without a_{13} .

X_2^2 will be multiplied by each element of the second column. In the expression for X_2^2 , a_{32} appears only once and with a_{23} , so the terms that result from multiplying X_2^2 by a_{12} and a_{22} will not indicate any undesirable effects. The effects that are measured when X_2^2 is multiplied by $(-a_{32})$ represent third-round requirements for waste disposal exclusively (X_3^3), not induced effects for sector 1 or 2, so again no problem arises.

Finally, when X_3^2 is multiplied by the elements in the third column a_{32} will always appear with an element from the disposal sector production function, because the third column is the disposal sector production function.⁶

If scrap material is regarded as a joint product, the a_{12} element in the same example would represent the inputs of both scrap and primary products directly required per unit output in the recycling sector from the scrap producing sector. This element may be divided into two parts to differentiate between sales of primary output (a_{12} which is equal to the corresponding element in the previous formulation) and scrap material (a'_{12}) by the scrap generating activity. The a_{32} element now indicates only the waste generated per unit output in the recycling sector and no longer represents the input of scrap.

Reformulating the system in this manner, an examination of the round-by-round effects reveals that the system will force the scrap generating industry to increase production in order to supply scrap to the recycling sector. The second round requirements from the scrap generating sector would be, analagous to (6a):

$$(7) \quad x_1^2 = (a_{11}^2 + (a_{12} + a'_{12})a_{21} + a_{13}a_{31})Y_1 + (a_{11}a_{12} + (a_{12} + a'_{12})a_{22} + a_{13}a_{32})Y_2 + (a_{11}a_{13} + (a_{12} + a'_{12})a_{23} + a_{13}a_{33})Y_3$$

Therefore,

$$(7a) \quad \frac{\partial x_1^2}{\partial Y_2} = a_{11}a_{12} + (a_{12} + a'_{12})a_{22} + a_{13}a_{12}$$

Relation (8a) represents the change in the scrap generating sector's second round output requirements corresponding to an increase in the final demand for the products of the recycling industry. The presence of the a'_{12} element indicates that the output of the scrap generating industry is increased in the system in order to satisfy the second round requirements for scrap when treated as a joint product.

A distinction has been made between primary products and joint products, for which the firm will increase its output in response to increased demand, and byproducts, which the firm will not produce to satisfy increasing demands. In some cases, the distinction may not be completely clear, and it might be more realistic to use the conventional method to introduce these particular scrap transactions in the table. Usually, however, scrap should be treated as a byproduct that does not effect the firm's decision about output levels.

The Economic Repercussions of Recycling

The following numerical example is presented to demonstrate the use of input-output analysis in projecting waste generation and illustrate the type of economic effects that may be expected from recycling. The structural matrix, balance equation form and inverse matrix for a hypothetical three-sector economy without

recycling appears below. As before, Sector 1 generates waste and the third sector produces waste disposal services. Initially, Sector 2 neither recycles or generates waste so that no negative elements are included in the structural matrix ($a_{32} = 0$).

$$(8) \quad A = \begin{bmatrix} .25 & .40 & 0 \\ .14 & .12 & .20 \\ .50 & 0 & 0 \end{bmatrix}$$

$$(I - A) X = Y$$

$$(8a) \quad \begin{bmatrix} .75 & -.40 & 0 \\ -.14 & .88 & -.20 \\ -.50 & 0 & 1.00 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

$$1 - a_{11} = .75 > 0$$

$$(8b) \quad 1 - a_{22} = .88 > 0$$

$$1 - a_{33} = 1.00 > 0$$

$$|I - A| = .564$$

$$X = (I - A)^{-1}Y$$

$$(8c) \quad \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} 1.56 & .71 & .14 \\ 1.43 & 1.33 & .27 \\ .78 & .35 & 1.08 \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

The inverse matrix, $(I - A)^{-1}$, indicates the total direct and indirect output requirements per unit of exogenous final demand for each sector. Notice that although Sector 2 does not directly generate waste ($a_{32} = 0$ in A), it does require inputs from Sector 1 ($a_{12} = .40$), the waste generating industry, and therefore indirectly forces the system to produce additional disposal services. This effect is captured in the inverse matrix, $(I - A)^{-1}$, which indicates that a total of .35 units of waste disposal services are required directly and indirectly to satisfy each unit of final demand for Sector 2 products. The total environmental and economic impact of particular activities may be evaluated by examining the inverse of the input-output system and the input-output table may also be used to predict total outputs, including waste generation, corresponding to different levels of final demand or changes in exogenous demand patterns.

Next let us introduce recycling into the system. Suppose that Sector 2 uses .10 units of scrap material inputs for every unit of output it produces. With this modification the same example appears as below:

$$(9) \quad A = \begin{bmatrix} .25 & .40 & | & 0 \\ .14 & .12 & | & .20 \\ .50 & -.10 & | & 0 \end{bmatrix}$$

$$(9a) \quad (I-A) = \begin{bmatrix} .75 & -.40 & | & 0 \\ -.14 & .88 & | & -.20 \\ -.50 & .10 & | & 1.00 \end{bmatrix}$$

$$1 - a_{11} = .75 > 0$$

$$(9b) \quad 1 - a_{22} = .88 > 0$$

$$1 - a_{33} = 1.00 > 0$$

$$|I - A| = .579 > 0$$

$$(9c) \quad (I-A)^{-1} = \begin{bmatrix} 1.55 & .69 & | & .14 \\ .41 & 1.30 & | & .26 \\ .74 & .22 & | & 1.04 \end{bmatrix}$$

Notice that although Sector 2 absorbs scrap material directly ($a_{32} < 0$ in the structural matrix A) the overall effect of the recycling sector is to generate waste. The inverse multiplier of the second sector on the waste disposal sector indicates that directly and indirectly .22 units of waste disposal services must be produced for every unit of output supplied by Sector 2 to final demand. Essentially Sector 2 generates more waste indirectly than it recycles and one might question whether this should be considered a recycling industry.

Notice also, however, that every element of the inverse matrix is smaller with the inclusion of recycling, compare $(I-A)^{-1}$ in (8c) and (9c). This means that to satisfy a given set of final demands, less output is necessary for an economy that recycles. For example, suppose 100 units of final consumption is demanded from both Sector 1 and Sector 2 and no final demand for waste disposal services exists in the economy hypothesized in the example. The total outputs required to satisfy these final demands in the economy without recycling are:

$$X = (I - A)^{-1}Y$$

$$(8d) \quad Y = \begin{bmatrix} 100 \\ 100 \\ 0 \end{bmatrix} \quad X = \begin{bmatrix} 227 \\ 176 \\ 113 \end{bmatrix}$$

The system with recycling requires the following total outputs from each sector:

$$(9d) \quad Y = \begin{bmatrix} 100 \\ 100 \\ 0 \end{bmatrix} \quad X = \begin{bmatrix} 224 \\ 171 \\ 96 \end{bmatrix}$$

Observe that recycling lowers not only the disposal requirements but the total output of the other sectors as well. This may be explained by indirect effects similar to those mentioned with respect to waste generation. Recycling directly reduces waste disposal requirements so that the waste disposal sector uses fewer inputs from the other sectors. These same sectors, one step further back require fewer inputs from one another which again lowers total outputs and also means less waste generation, and so on.

This result is similar to the ideas of Kenneth Boulding [1966] who argues that the earth should be regarded as a "spaceship" with limited and finite amounts of resources. The objective of a spaceship economy would be to maximize output while minimizing "throughput" or economic activity. Recycling, as has been shown, does just this. Regional analysis, in contrast, often emphasizes maximizing employment or GRP in examining local multipliers which often leads to maximization of throughput. Conventional wisdom thus regards heavy use of resources as good.

It should be pointed out that whether or not recycling actually reduces total outputs in any application is an empirical question. The example presented above, although useful for illustration, is an oversimplification of reality. The effects of recycling depend on actual waste disposal costs, the costs of recovering scrap materials, and the entire pattern of structural relationships for the economy under consideration. In the example, no additional costs for the collection, processing, and recovery of scrap materials were incurred when recycling was introduced (although no input requirements were lowered to account for the substitution of scrap for other materials either). Scrap recovery may be so expensive that it negates savings in disposal costs.

Also, for many regions an increase in recycling is likely to stimulate the local economy due to substitution of goods produced with indigenous scrap materials for commodities that would otherwise be imported. Recycling might then be considered a new basic industry for urban areas and the interregional redistribution of employment and income would be of interest.

Constraints on Final Demand

It is also possible that the recycling element in the structural matrix (a_{32} in the examples) is large enough to cause the corresponding element in the inverse matrix to be negative so that the net effects of the recycling activity are to reduce the waste disposal requirements for the system. Consider the following example which is identical to the preceeding ones except for a larger recycling element.

$$(10) \quad A = \begin{bmatrix} .25 & .40 & | & 0 \\ .14 & .12 & | & .20 \\ .50 & -.30 & | & 0 \end{bmatrix}$$

$$(10a) \quad (I-A) = \begin{bmatrix} .75 & -.40 & | & 0 \\ -.14 & .88 & | & -.20 \\ -.50 & .30 & | & 1.00 \end{bmatrix}$$

$$(10b) \quad \begin{aligned} 1 - a_{11} &= .75 > 0 \\ 1 - a_{22} &= .88 > 0 \\ 1 - a_{33} &= 1.00 > 0 \end{aligned}$$

$$|I-A| = .609 > 0$$

$$(10c) \quad (I-A)^{-1} = \begin{bmatrix} 1.54 & .66 & | & .13 \\ .39 & 1.23 & | & .25 \\ .65 & -.04 & | & .99 \end{bmatrix}$$

The inverse matrix of an input-output table may be used, as in the example, to predict the total output required in each sector to satisfy a particular set of final demands. The total outputs represent the amount of goods and services produced by various industries so that negative total outputs ordinarily have little interpretation. Since the inputs of each sector are outputs of the other activities in the model it is normally assumed that any level of output and therefore any amount of exogenous demand may be achieved by the economy with sufficient expansion in the appropriate sectors. For conventional input-output models the Hawkins-Simon conditions (Hawkins and Simon [1949]) are necessary and sufficient to insure that any set of nonnegative final demands may be associated with a corresponding set of nonnegative total outputs.

$$(11) \quad \begin{aligned} 1 - a_{ii} &> 0 \\ |I-A| &> 0 \end{aligned}$$

These conclusions must be modified for the augmented input-output model. The Hawkins-Simon conditions (11) are based on the assumption that there are no negative intermediate demands, or in other words, no negative elements in the structural matrix (A) of the system. Recycling is represented by negative elements in off-diagonal positions of the input-output structural matrix

indicating negative intermediate demand for waste disposal services by the recycling industry. As has been shown this may (11c) or may not (10c) result in the appearance of negative elements in the inverse matrix. If there are negative inverse elements, some sets of final demands will imply negative outputs and are therefore infeasible for the economy even though the Hawkins-Simon conditions are satisfied by the model (notice that none of the examples violates the Hawkins-Simon conditions; see (8b), (9b) and (10b)).

For example, the following final demand vector requires a negative output of waste disposal services in the intensive recycling example (12).

$$(10d) \quad Y = \begin{bmatrix} 10 \\ 200 \\ 0 \end{bmatrix} \quad X = \begin{bmatrix} 147.4 \\ 249.9 \\ -1.5 \end{bmatrix}$$

The negative output of disposal services is the result of the demand for scrap material exceeding the amount of recoverable waste available. In conventional input-output systems goods are assumed to be produced automatically in response to exogenous or intermediate demands. Scrap material, however, is generated as a byproduct in producing other goods and services. The model was therefore formulated, as discussed previously, so that the

supply of scrap material is unrelated to the demand for it but rather governed by the outputs in scrap generating sectors. A negative output of disposal services indicates that the final demand for recycled products is so large that the recycling industry requires more scrap material than is generated by the system. Recall that recycling reduces the demand for waste disposal services so that when the demand for scrap exceeds waste generation the net waste disposal requirements for the system will be less than zero.

Although solid waste is abundant, specific types of scrap material may be in short supply. Certainly, some regions would not generate enough scrap material to support large recycling industries. This type of model therefore might be used to determine the level of recycling activity that would be feasible for various regions. Of course, the possibility of importing scrap material could also be considered in an actual application.

Given a set of nonnegative final demands, the only possibility for negative output is in the waste disposal sector, since negative coefficients in the inverse matrix will only occur in the row that corresponds to this sector. This property allows the formulation of an additional condition on final demand vectors to insure nonnegative total outputs. The total output in

the waste disposal sector (X_d) may be written as

$$(12) \quad X_d = \sum_j \alpha_{dj} Y_j + \sum_r \alpha_{dr} Y_r$$

where: α_{dj} = total direct and indirect requirements of waste disposal for waste type d per unit output in waste generating sector j . These are coefficients in the waste row of the inverse matrix $(I-A)^{-1}$ for waste generating sectors. These elements will be nonnegative ($\alpha_{dj} \geq 0$).

α_{dr} = the total direct and indirect requirements of recycling industry r for waste disposal services. These coefficients are also elements of the waste disposal row d of the inverse matrix ($\alpha_{dr} \geq 0$).

A given final demand vector is feasible if $X_d \geq 0$, or:

$$(12a) \quad \sum_j \alpha_{dj} Y_j \geq - \sum_r \alpha_{dr} Y_r$$

In words, the total output of the waste disposal sector must be nonnegative or the system must generate more scrap than is required for recycling.

Price Effects

Prices as well as outputs are altered when recycling is included in the system. The linear programming interpretation of an input-output system (Dorfman, Samuelson, and Solow [1958])

allows us to investigate price effects. The linear programming determination of outputs is:

$$\begin{aligned}
 (13) \quad & \text{minimize } w a_{01} X_1 \\
 & \text{subject to } (I-A)X \geq Y
 \end{aligned}$$

where w = wage rate, and a_{01} = labor input per unit output in Sector 1. Subject to the production of a specified bill of goods (Y), choose gross outputs to minimize total labor costs (labor is assumed to be the only value added item and thus the sole cost-generating factor in the system).

The dual to this program is:

$$\begin{aligned}
 (14) \quad & \text{maximize } pY \\
 & \text{subject to } (I-A)'p \leq (a_{01}w)'
 \end{aligned}$$

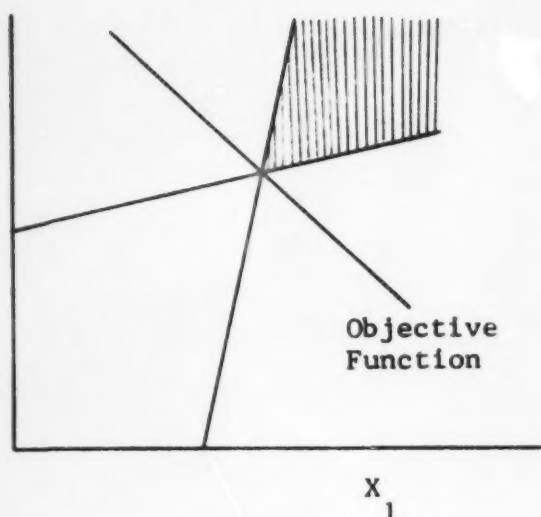
where p_i is interpreted as the shadow price on the output from Sector 1. Subject to price-cost inequalities, choose prices to maximize the value of net output. The price-cost inequalities conform to the assumption of long-run competitive equilibrium.

A diagrammatic representation of a two sector input-output system in linear programming form is shown below:

PRIMAL

(13a)

x_2



$$\text{minimize } wa_{01}x_1 + wa_{02}x_2$$

subject

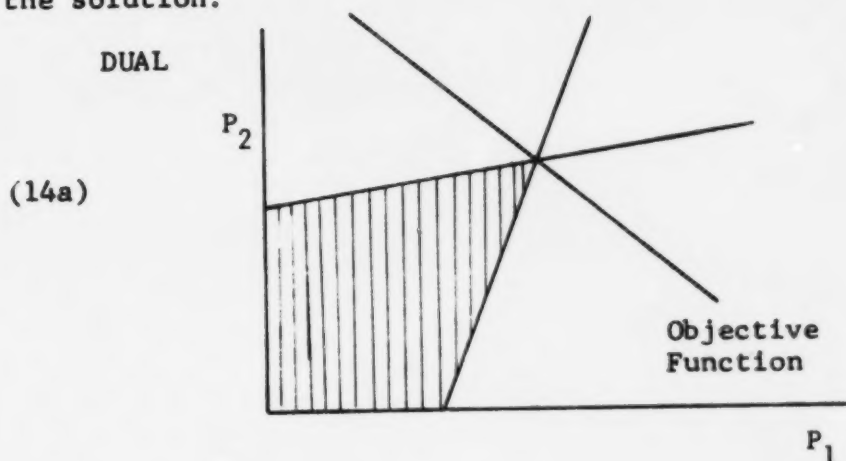
$$\text{to: } (1 - a_{11})x_1 - a_{12}x_2 \geq Y_1$$

$$-a_{21}x_1 + (1 - a_{22})x_2 \geq Y_2$$

The shape of the feasible region is such that any negatively-sloped objective function will result in the same solution.

Because of this, the input-output system can be solved as a set of simultaneous equations and it is not necessary to solve the linear program. A change in the amount of labor or other value added factor per unit output in any sector (a_{0i}) will not change the total output solution for a fixed set of final demands (as long as the table is not closed for the household sector) as a change in the labor coefficients just changes the slope of the objective function.

A change in final demand (Y_1) results in a parallel shift of a constraint and a new total output solution. Technological change, or a change in the coefficients of the structural matrix (a_{ij}), alters the slope of the constraints and will also change the solution.



$$\text{maximize } Y_1 P_1 + Y_2 P_2$$

subject

$$\text{to: } (1 - a_{11})P_1 - a_{21}P_2 \leq a_{01}w$$

$$-a_{12}P_1 + (1 - a_{22})P_2 \leq a_{02}w$$

Similar conclusions may be made for the dual to the input-output system. The same shadow prices apply for any set of final demands (Y_1), since a change in final demand only changes the slope of the objective function. A change in labor inputs per unit output in a sector means a parallel shift in a constraint. Alterations in input mix varies the slope of the constraints. Both result in a new set of shadow prices.

Simulating the effects of new recycling possibilities and disposal technologies involves alterations in the structural coefficient matrix. In terms of the above discussion, this means modifying the constraint set of the system. Both total outputs and dual prices may be anticipated to change.⁷

The balance equations between prices and value added for the hypothetical three-sector economy with a waste disposal sector appears below.

$$(15) \quad \begin{bmatrix} 1 - a_{11} & -a_{21} & -a_{31} \\ -a_{12} & 1 - a_{22} & +a_{32} \\ -a_{13} & -a_{23} & 1 - a_{33} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} = \begin{bmatrix} a_{01}w \\ a_{02}w \\ a_{03}w \end{bmatrix}$$

$$\begin{aligned} p_1 - a_{11}p_1 - a_{21}p_2 - a_{31}p_3 &= a_{01}w \\ (15a) \quad p_2 - a_{12}p_1 - a_{22}p_2 + a_{32}p_3 &= a_{02}w \\ p_3 - a_{31}p_1 - a_{23}p_2 - a_{33}p_3 &= a_{03}w \end{aligned}$$

The first equation is the price-cost relationship for the waste generating sector. It reads: the price of a unit of output from Sector 1, minus the cost of inputs from Sector 1 per unit of Sector 1 output (a_{11} units of intermediate demand at a price of p_1 per unit), minus the cost of inputs from Sector

2 ($a_{21}p_2$), minus the cost of waste disposal required per unit output in Sector 1 (a_{31} units of waste created and requiring disposal at a cost of p_3 per unit), must equal the labor cost per unit output in Sector 1 ($a_{01}w$). Similarly, for the waste disposal sector, the third equation requires that the price of one unit of disposal minus the costs of inputs from the other sectors and the cost of disposing of waste created by the disposal process cannot exceed value-added in the disposal sector per unit output.

The second equation corresponds to the recycling sector. Here the unit price of Sector 2 output minus the cost of inputs from Sectors 1 and 2 per unit output plus the amount of scrap recycled input per unit output times the unit cost for waste disposal must not be greater than value added per unit in the recycling sector. The sector gets a subsidy for recycling equal to the disposal costs that are avoided because the recycling sector absorbs waste that would otherwise require disposal services.

Comparison of systems with and without recycling will reveal that recycling has a tendency to lower the shadow prices for all sectors. The recycling industry is credited with a subsidy for avoiding disposal costs on the scrap inputs, which reduces the shadow price on recycled outputs. The other sectors

receive inputs from the recycling industry at a lower price, and thus their costs for intermediate inputs and their shadow prices are smaller.⁸ Again, whether or not recycling will reduce shadow prices in any application depends on the actual costs of waste disposal and scrap recovery as well as the structure of the economic system.

Application of the Model

Refinements for Practical Applications

An actual application of an augmented input-output system would, of course, be more elaborate than the simple examples that have been used here. Sectors devoted to the recovery of scrap materials would be included, so that the cost of recycling solid waste is accounted for. These would be treated as wholesalers whose output is defined as the service of collecting, processing and transporting scrap materials and is measured in terms of margin (the value of goods sold minus the value of materials purchased). Recycling industries would therefore receive inputs of scrap dealers' services as well as physical units of scrap materials.

Waste generation coefficients might be disaggregated according to type of waste materials. The table would then predict not only the total amount of solid waste generated but also the amount of each type of waste material. This information is essential for evaluating recycling activities and is important for disposal, as well. Projections of the proportions of combustible and non-combustible solid waste, for example, are helpful in planning disposal facilities.

Additional disaggregation of the waste generation coefficients might be done on the basis of the geographic origin of the refuse. Since transportation accounts for the largest part of disposal costs, detail of this type would allow more accuracy in predicting disposal costs. The model could be made to project expected transportation requirements explicitly as well as facilities necessary for actual disposal.

Several types of disposal methods could be included in the system, and the disposal sectors might be disaggregated according to location. The model would then allocate a certain proportion of each type of refuse material generated in each subregion to every disposal facility. Dummy sectors would be included in the structural matrix for this purpose.

For example, the structural matrix that appears below represents a system in which two types of waste are distinguished and two different waste disposal processes are available.

$$(16) \quad A = \left[\begin{array}{cc|cc|cc} a_{11} & a_{12} & a_{13} & a_{14} & & \\ a_{21} & a_{22} & a_{23} & a_{24} & \emptyset & \\ \hline & & & & d_{13} & d_{23} \\ & & & & d_{14} & d_{24} \\ \hline w_{11} & -w_{12} & w_{13} & w_{14} & & \\ w_{21} & w_{22} & w_{23} & w_{24} & \emptyset & \end{array} \right]$$

The first column represents a conventional economic sector. The production function in the second column corresponds to the recycling sector. The recycling sector again has a negative intermediate demand for disposal service (an input of scrap material designated by w_{12}) but notice that this sector recycles only one type of scrap and requires disposal services for other waste materials. The two disposal sectors are represented by the third and fourth columns.

The last two columns are dummy sectors. The non-zero elements in each column show the proportion of each type of refuse allocated to each disposal sector. That is, d_{13} percent of waste type 1 goes to disposal sector 3 and d_{14} percent goes to disposal sector 4, where ($d_{13} + d_{14} = 1$).

The general form of the more elaborate model would be:

$$(17) \quad \left[\begin{array}{ccc|ccc} I - A_{11} & & -A_{12} & & & \emptyset \\ & \emptyset & & I & & -D \\ -A_{21} & & -A_{22} & & & I \end{array} \right] \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

where A_{11} , A_{12} , A_{21} , A_{22} , X_1 , Y_1 and Y_2 have the same interpretations as before (1), and

$D = [d_{gk}]$ = proportion of waste g allocated to disposal sector k .

$X_2 = [x_k]$ = total amount of waste disposal services produced by disposal sector.

$X_3 = [x_g]$ = total amount of waste g requiring disposal services.

Uses of the Model

Given a set of final demands, an augmented input-output model could be used to predict total output in each sector, the amount of solid waste generated by the economy, composition of the waste load by type of material, the quantity of scrap materials that are salvaged, and the amount of waste disposal services required. For an impact study, the table would predict the effects of changes in final demand on waste disposal activities as well as outputs in other sectors of the economy.

The model might also be used to evaluate the effects on the local economy of using different methods of waste disposal, implementing recycling projects, or putting into effect policies designed to decrease waste generated. With regard to recycling projects, the model would project whether or not enough of a particular type of material would be available to satisfy demands for recycling inputs, and changes in the outputs of various economic sectors caused directly and indirectly by the increased

use of salvaged material. Output changes may be converted into employment effects.

In order to simulate the effects of a new recycling activity, a sector representing the recovery process might be added to the table. The column vector for the new sector would show its inputs of products from other sectors and scrap materials. The row vector corresponding to the sector would indicate the distribution of recycled products to other sectors. These coefficients might also be altered to investigate the economic effects of alternative marketing patterns for recycled products.

The output levels for the various sectors in the regional system for a given set of final demands might be compared before and after the introduction of the new recycling industry. Similar procedures have been used in regional development planning (Miernyk [1970]). The input-output analysis would give estimates of the outputs in the recycling sector that are consistent with both the markets hypothesized for the recycled products and the general level of economic activity in the region. If economies of scale are relevant to the particular recycling operation and some minimum level of output is required for the project to be economically feasible, such projections could be quite valuable.

The regional redistribution effects at a recycling activity might also be estimated. As mentioned, recycling in many cases will involve the substitution of indigenous scrap material for inputs imported from other regions. If it is true that recycling creates new "basic" industries for urban regions, the amount of employment created locally in comparison to the number of jobs lost in other regions would be an important factor for policy decisions on whether or not to encourage recycling.

Finally, there are tradeoffs between different aspects of environmental quality. An augmented input-output model with air and water pollution coefficients as well as solid waste coefficients specified could be useful in analyzing the relationships between different types of environmental considerations.

Limitations of the Model

It is important to recognize some of the limitations inherent in this type of analysis. The model presented here will predict the amount of waste generated in a region, but it does not give estimates of the damages that might be caused by the refuse or pollutants. Knowledge of the amounts of the residuals is nevertheless essential for estimating the damages involved.

Input-output analysis assumes that production takes place with inputs combined in constant proportions. This type of pro-

duction function precludes substitution between factors of production and economies of scale effects. The assumption is really less restrictive than it may appear to be. The choice of inputs in many production processes is governed by technical considerations and significant technological changes usually take place incrementally for an entire economy. In many cases, solid waste is generated in repetitive processes, a certain amount of material being lost in the production of each item, so that the fixed coefficients may not be a serious shortcoming in predicting waste generation. Similar reasoning may not be realistic for air or water pollution, however.

The fixed coefficients do impose some inflexibility on the model. If some proportion of a certain category of waste is to be allocated to one disposal site, the system may produce results that exceed the capacity of the facility. Problems of this type can be overcome by skillful manipulation of the model such as altering coefficients between the rounds in round-by-round estimation of impacts.

Data Requirements

Also, the usefulness of these techniques for any practical application depends on the quality of the data used to estimate the model parameters. The following kinds of data are required

to augment an existing input-output table to account for solid waste generation and disposal:

1. A set of coefficients that indicate the amount of waste generated per dollar output in each sector. It would be desirable to have coefficients disaggregated as much as possible both by economic sector and types of materials. As discussed before, the coefficients should show all byproducts generated whether they are sold as scrap or require disposal.
2. Information on the amounts and types of inputs required for waste disposal. Production functions for incineration and landfill should be known along with differences in costs for private and publicly operated disposal facilities. Costs for various types of collection and transportation systems should also be determined.
3. The model requires knowledge of the amount of salvaging done in the region studied.
4. Finally, alternative disposal systems, recycling activities, or policies that are to be evaluated must be investigated in depth. Detailed information on the particular processes and costs must be obtained.

Summary

A method of integrating recycling activities as well as solid waste generation and disposal into an input-output model is described in this paper. The conventional input-output system is augmented by including additional sectors to trace the flows of waste byproducts. Coefficients that express waste disposal requirements, measured in physical units of solid waste, per unit output in each economic sector appear in rows of the input-output table. Columns corresponding to these rows express the input requirements of sectors that produce waste disposal services.

Recycling diverts materials generated as byproducts to uses as raw materials in the production of saleable goods. A recycling sector's input of scrap material therefore appears in the model as a reduction in waste disposal services required for the system. The amount of scrap generated by the system is governed by the level of activity in the industries that generate usable byproducts and is not influenced by the demand for scrap materials. The demand for scrap determines only the quantity that is recovered and usable scrap materials revert to the solid waste stream if insufficient demands are created for recycling. This avoids the unrealistic effect of demands for scrap material

inducing increased output from scrap producing industries.

As has been shown, the inclusion of recycling in the input-output system in this fashion leads to several conclusions about the economic effects of recycling and applications of input-output analysis. Recycling has a tendency to decrease the total output required from all economic sectors to satisfy a given set of exogenous final demands. Similarly, recycling tends to reduce shadow prices and input-output techniques can be useful in determining appropriate subsidies for scrap recovery activities.

In addition, the method used to handle recycling in the system implies that certain levels of output, and therefore certain sets of final demands, may require more scrap material than is produced in the system. With the inclusion of recycling, it is no longer assumed, as in conventional input-output models, that any amounts of final demand may be satisfied by sufficient expansion in the appropriate sectors of the economy but rather there are constraints on final demands governed by the availability of scrap. Another application of input-output analysis is in determining the recycling potential of an economic system.

The model could also be used to project waste disposal requirements for various regions and in simulating the economic and environmental impacts of alternative recycling programs and

regional waste disposal systems. The Regional Science Research Institute has made considerable progress in implementing an augmented input-output system of this type based on the Philadelphia Regional Input-Output Model (Isard, Langford and Romanoff [1969]). A comprehensive set of waste generation coefficients has been developed specifying waste generation rates of various waste materials for manufacturing industries at the four-digit SIC level of aggregation (Steiker [1973]), as well as non-manufacturing activities (Kontuly [1974a]). In addition, data on costs have been assembled for various waste disposal processes including collection, transportation, transfer stations, incineration, and landfilling (Kontuly [1974b]). Information is currently being gathered on scrap recovery processes and recycling activities.

FOOTNOTES

1. The reader unfamiliar with input-output analysis is referred to one of several explanations of input-output theory and applications available. See Miernyk [1970] or Dorfman, Samuelson and Solow [1958].
2. The Philadelphia Table (Isard, Langford and Romanoff [1967]) includes more than 400 sectors disaggregated to 4-digit SIC categories.
3. The formulation has been modified in one respect with regard to Leontief's model. In the original article (Leontief [1970]) the coefficients in the structural matrix below the partition (A_{21} and A_{22}) were interpreted as outputs of pollution or waste and were given a sign opposite to that of the ordinary structural coefficients (A_{11} and A_{12}), which represent inputs. In this system, the waste generation coefficients have the same sign as the usual structural coefficients and may be interpreted as inputs of waste disposal services. The two interpretations are equivalent since it is assumed that every unit of waste generated requires a unit of disposal services. The new interpretation, however, makes the explanation that follows less confusing.
4. The incineration of solid waste results in a smaller amount of ash residue, for example.
5. The superscript indicates the round and the subscript the sector, so X_2^1 denotes the requirements from sector 2 in round 1.
6. When the inverse to this simple system is calculated, a_{32} also appears with an element from the disposal column in all appropriate places.

In general, for a square matrix B,

$$B^{-1} = 1/|B| [\text{adj. } B]$$

Therefore, in the case of the three sector input-output model,

FOOTNOTES - cont.

$$(I-A)^{-1} = \frac{1}{|I-A|} \begin{bmatrix} (1 - a_{33} - a_{22} + a_{22}a_{33} + a_{32}a_{23}) & (a_{12} - a_{12}a_{33} - a_{32}a_{13}) & (a_{12}a_{23} + a_{13} - a_{22}a_{13}) \\ (a_{21} - a_{21}a_{33} + a_{31}a_{23}) & (1 - a_{33} - a_{11} + a_{11}a_{33} - a_{31}a_{13}) & (a_{23} - a_{11}a_{23} + a_{21}a_{13}) \\ (-a_{21}a_{32} + a_{31} - a_{31}a_{22}) & (-a_{32} + a_{11}a_{32} + a_{31}a_{12}) & (1 - a_{22} - a_{11}a_{22} - a_{11} - a_{21}a_{12}) \end{bmatrix}$$

so that, for example:

$$\frac{\partial x_1}{\partial y_2} = \frac{+a_{12} - a_{12}a_{33} - a_{32}a_{13}}{(1 - a_{11} - a_{22} - a_{33} + a_{22}a_{11} + a_{33}a_{22} + a_{33}a_{11} - a_{33}a_{22}a_{11} - a_{12}a_{23}a_{31} + a_{13}a_{32}a_{21} - a_{31}a_{13} + a_{31}a_{22}a_{13} - a_{21}a_{12} + a_{21}a_{12}a_{23} + a_{23}a_{32} - a_{23}a_{32}a_{11})}$$

- 7.. David Berry suggested these points in one of our many discussions.
8. The same examples used to demonstrate output effects (9), (10) and (11) can be used to demonstrate this point. The balance equations for price and value-added are

$$(I-A)' p = V$$

therefore

$$p = (I-A)'^{-1}V$$

The relevant inverse matrix is therefore the transpose of the inverse $(I-A)^{-1}$ of the output system. As before, every element of this inverse becomes smaller when recycling is introduced into the system so that with given amounts of value-added in each industry (V), shadow prices (p) will be smaller for a system with recycling.

REFERENCES

- Ayres, L., I. Gutmanis and A. Shapanka. Environmental Implications of Technological and Economic Change for the United States, 1967-2000: An Input-Output Analysis. Report prepared for Resources for the Future, Inc., International Research and Technology Corporation, Washington, D.C., June 1971.
- Ayres, R. V. and A. V. Kneese. "Production, Consumption and Externalities," American Economic Review, Vol. 59, June 1969.
- Converse, A. O. "On the Extension of Input-Output Analysis to Account for Environmental Externalities," American Economic Review, Vol. 61, March 1971, pp. 197-198.
- Council on Environmental Quality. Environmental Quality, First Annual Report of the CEQ. U.S. Government Printing Office, August 1970.
- Cumberland, J. H. and B. N. Stram. "Economic Flows and Environmental Coefficients," The Review of Regional Studies, Vol. II, Spring 1972, pp. 28-40.
- Dorfman, R., P. A. Samuelson, and R. M. Solow. Linear Programming and Economic Analysis, McGraw-Hill Book Co., New York, 1958.
- Gouleke, C. G. Comprehensive Studies in Solid Waste Management, Environmental Protection Agency, 1971.
- Hawkins, D. and H. A. Simon. "Note: Some Conditions of Macroeconomic Stability," Econometrica, Vol. 17, July-October 1949, pp. 245-248.
- Hite, J. C. and E. A. Laurent. "Empirical Study of Economic-Ecological Linkages in a Coastal Area," Water Resources Research, Vol. 7, October 1971, pp. 1070-1078.
- Herfindahl, O. C. and A. V. Kneese, "Measuring Social and Economic Change: Benefits and Costs of Environmental Pollution," in Measurement of Economic and Social Performance, M. Moses, ed., National Bureau of Economic Research, New York, 1973.
- Isard, W. et al. "On the Linkage of Socio-Economic and Ecological Systems," Papers, RSA, Vol. 21, 1968, pp. 79-99.

- Isard, W., C. L. Choguill, J. Kissin, R. H. Seyfarth, Tatlock, et al. Ecological-Economic Analysis for Regional Development, The Free Press, New York, 1972.
- Isard, W., T. W. Langford, Jr. and E. Romanoff. Philadelphia Region Input-Output Study, Working Papers, Department of Regional Science, University of Pennsylvania and Regional Science Research Institute, Philadelphia, 1967.
- Kontuly, Thomas. "Production Functions for Solid Waste Disposal" unpublished memo, RSRI, March 1974(a).
- Kontuly, Thomas. "Solid Waste Generation Coefficients: Non-manufacturing Sectors," unpublished memo, RSRI, March 1974(b).
- Leontief, W. "Environmental Repercussions and Economic Structure: An Input-Output Approach," Review of Economics and Statistics, Vol. 52, August 1970, pp. 262-271.
- Miernyk, W. H. The Elements of Input-Output Analysis, Random House, New York, 1967.
- Miernyk, W. H. et al. Simulating Regional Economic Development, D.C. Heath and Company, Lexington, 1970.
- Noll, R. G. and J. Trijonis. "Mass Balance, General Equilibrium and Environmental Externalities," American Economic Review, Vol. 61, September 1971, pp. 730-735.
- Randers, J. "The Dynamics of Solid Waste Generation," unpublished paper, The Club of Rome Project on the Predicament of Mankind. System Dynamics Group, Alfred P. Sloan School of Management, MIT, June 1, 1971.
- Romanoff, E. "Material Reclamation Industries in Regional Economies," Paper presented at the 1972 IEEE Conference on Decision and Control, New Orleans, La., December 1972, Regional Science Research Center, Cambridge, Mass., September 1972.
- Steiker, G. "Solid Waste Coefficients: Manufacturing Sectors," RSRI Discussion Paper Series: No. 61, December 1973.

III. SOLID WASTE GENERATION COEFFICIENTS: MANUFACTURING SECTORS*

Introduction

Recent concern over environmental deterioration has stimulated interest in more effective management of environmental resources. Public and private decision makers must be able to make accurate estimates of the quantities of pollutants generated and make reliable assessments of repercussions caused by alternative policies in order to find solutions to environmental problems. Unfortunately, the methods and particularly the data base pertaining to many environmental questions are inadequate for effective planning.

The introduction of new technology for the collection and disposal of solid wastes, better institutional arrangements such as regional cooperation in providing disposal facilities, government regulation to maintain health and environmental standards, and increased recycling are necessary improvements that require careful planning and accurate prediction. Methods must be developed that will be useful in making projections of solid waste generation that are consistent with the level of economic activity, in planning solid waste disposal systems that are adequate in terms of both capacity and environmental requirements, and in evaluating the effects of recycling activities and then policy alternatives.

*Chapter III written by Gene Steiker

Problems involved in the disposal of solid waste have only recently received attention. Although the quantity of waste generated is increasing rapidly and disposal is becoming more costly and difficult especially in urban areas, little reliable information exists on the subject.¹ Only crude approximations exist as to the amount of solid waste generated. Few municipalities keep good records on the collection and disposal of solid waste. What information exists is often difficult to interpret because of differences in local practices, such as whether commercial establishments or multifamily dwellings are provided with municipal waste disposal services.² Less information is available on wastes generated by industrial and commercial establishments which are handled either by the firms themselves or the private waste disposal industry.

Estimates of waste generation are usually made by using rule-of-thumb factors for waste generation per capita.³ Several sets

¹ See Council on Environmental Quality [1970] for a summary of solid waste problems.

² American Public Works Association [1966] includes an analysis of the variations in municipal waste disposal practices.

³ A commonly used figure is 6.9 lbs. per person per day, Combustion Engineering [1970], pp. 9-13.

of highly aggregated waste generation coefficients have been estimated for manufacturing sectors.⁴ Improved methods for relating waste generation to levels of economic output are needed. Input-output analysis is particularly suitable for economic-environmental studies. An input-output model provides a comprehensive view of an economy and forecasts of output by detailed industrial categories. Disaggregation allows flexibility in specifying technical and economic relationships, locational considerations, and even the inclusion of entirely new activities.⁵

Implementation of such a model requires a set of coefficients that specify the amount of waste generated per unit output by each industry in the economy. Solid waste generation coefficients are presented in this paper for 342 manufacturing industries at the

⁴See Camp, Dresser and McKee [1972], Commonwealth of Pennsylvania [1970], Combustion Engineering [1970], Cumberland and Stram [1972], Goulueke and McGauhey [1970], Hite and Laurent [1971], and Oregon [1970]. Each was judged inadequate for the purposes of this project. Most of this information is for industries aggregated to two-digit SIC categories and all of the studies rely on small samples. Wide variation in waste generation rates are evident and attributable to differences in industrial mix for the various sampling regions. Only two sources, Cumberland and Stram [1972] and Oregon [1970], include information on the types of refuse materials generated. Detailed analysis of waste generation in particular industries is rare [Pettigrew, et al.]

⁵The adaptation of input-output methodology for evaluating environmental questions has been discussed by a number of writers. See Isard [1972], Ayres and Kneese [1969], Leontief [1970], Romanoff [1972]. Several economic-environmental input-output models have been implemented, including Hite and Laurent [1971], Ayres and Gutmanis [1971], and Cumberland and Stram [1972].

four-digit SIC level of aggregation. The coefficients are based on information gathered from firms in the Philadelphia area. For each sector coefficients have been estimated for thirteen types of refuse materials as well as total waste generated per employee. Based on coverage and sample size, these coefficients are the most complete and accurate data of this type available and should be useful for predicting waste generation and environmental modelling.

In the following section, the coefficients are described in more detail. Section III includes a summary of the data base. Difficulties in collecting information on solid waste are discussed in Section IV. In Section V the data are evaluated at different levels of aggregation and the coefficients are compared with results found in other studies. Section VI consists of a summary of findings and some concluding remarks.

Description of Coefficients

The major product of this research is a complete set of waste generation coefficients for 342 manufacturing sectors. These coefficients, in tons per employee per year, are presented as Appendix G. The following conventions were used in arriving at these results.

Data Base. The coefficients estimated in this study are based primarily on data collected from firms in the Philadelphia SMSA.⁶ A few Pennsylvania firms outside the Philadelphia SMSA were included in order to enhance the sample. In an effort to make the information as comprehensive as possible, coefficients based on surveys done in Texas and Kentucky are included in Appendix G for industries that were not adequately covered in the Philadelphia sample. All subsequent discussion, however, refers to the Philadelphia data.

Industrial Categories. Industrial categories are defined according to Standard Industrial Classification (U.S. Bureau of the Budget [1971]). SIC categories are generally accepted in eco-

⁶The Philadelphia SMSA includes Bucks, Chester, Delaware, Montgomery and Philadelphia counties in Pennsylvania, and Burlington, Camden and Gloucester Counties in New Jersey.

conomic practice and conform to the industrial sectors used in the Philadelphia Input-Output Table (Isard, Langford, and Romanoff [1971]). The system groups firms according to the kind of products produced and processes utilized. Categories become more detailed as digits are added successively to the identification numbers. For example, SIC 20 represents Food Products, SIC 201 is Meat Products, and SIC 2013 includes firms making Sausage and other Prepared Meat Products.

It was assumed that maximum possible disaggregation of industrial sectors was desirable in describing the waste generation traits of various activities since more aggregated sectors combine establishments with more dissimilar products and characteristics. The available data precluded disaggregation beyond the four-digit level.

Units of Measurement. The coefficients listed in Appendix G represent tons of waste generated per employee for each activity. Measures of waste quantities in terms of weight were considered superior to volume estimates since they do not vary under different conditions such as compaction.

Employment was used as the measure of output for reasons of data availability. Employment by establishment is available in

industrial directories and could be matched with waste generation information collected in previous surveys.

Unfortunately, it was not possible to compute coefficients directly in terms of waste generated per dollar output. The coefficients are to be used with input-output tables which by convention express output in dollar values. No published data are available on value of output by establishment, however, and firms are often reluctant to disclose such information. The coefficients were converted into dollar output terms using estimates of value of output per employee by sector.

Refuse Materials. For each sector coefficients have been specified for fourteen types of materials as well as for total waste generated per unit output. The detailed coefficients are useful both for evaluating recycling projects and in planning disposal facilities. The detailed coefficients may be combined to make separate predictions of combustible and non-combustible refuse, or of quantities of materials that require special handling (food processing wastes, for example).

The kinds of refuse covered in the survey include ordinary trash and solid wastes that are connected with specific production processes of various industries. Little information on hazardous

wastes were collected since business firms rarely were willing to give out this type of information. Although some data were gathered on sludges and other liquid waste, the information included in this study is particularly skimpy in this area. Generally, the coefficients for the individual types of waste may be regarded as less accurate than the estimates of total waste generation rates since many respondents had difficulty identifying the types of materials in their waste in any detail.

Scrap Sales. The coefficients developed in this study represent the total amount of byproducts generated per unit output in each sector including materials that are sold or given away to be reused as scrap. Only materials that are recycled internally and never leave the plant were excluded.

Whether or not a firm sells its byproducts as scrap depends on a variety of factors that may have little relation to the amount or type of byproducts generated. The size of the firm, its location, market conditions for scrap materials at any particular time, or special institutional arrangements may all be relevant. Coefficients based on the convention used in this study therefore would be subject to less variance than those representing only material requiring disposal. Also, the possibilities for input-

output analysis, especially in evaluating recycling activities, are expanded with this type of coefficient.⁷

⁷See Steiker [1974] on the use of input-output techniques to evaluate activities related to solid waste.

Data

Source of Data

Data for computing waste generation coefficients were taken from two existing surveys and from a survey carried out by the Regional Science Research Institute.

The Pennsylvania Industrial Solid Waste Inventory

The principal data base for the coefficients is a survey of industrial establishments conducted by the Pennsylvania Department of Environmental Resources in 1969.⁸ A copy of the questionnaire used in this survey is included as Appendix B. Information was collected in personal interviews with representatives of several thousand firms throughout the state. Although some analysis of the data has been done (Bucciarelli [1970], Commonwealth of Pennsylvania [1970]) the data have not previously been used to develop waste generation coefficients for four-digit industries.

Responses for firms in the Philadelphia SMSA were compiled into four-digit SIC groups and matched to employment data from industrial directories. This provided information on employment and waste generation for a sample of firms in most manufacturing

⁸Mr. Philip T. McGee of the Division of Solid Waste, Pennsylvania Department of Environmental Resources, made this information available.

sectors. Unfortunately, the survey covered a disproportionate number of small establishments and lacked information from many of the largest firms. For some sectors there were very small samples or no data at all. Information reported by some firms appeared to be incomplete and often the type of refuse material was not adequately specified. For these reasons additional information was sought.

The Pennsylvania Air Management Inventory

A survey of air pollution emissions done by the State of Pennsylvania provided a second source of data. Although the purpose of this survey was to establish an air pollution emissions inventory for the State, information about solid waste generation was also requested from cooperating establishments. The survey was conducted using both mailed questionnaires and personal interviews. A copy of the survey form is shown in Appendix C.⁹

⁹ Responses for establishments in Philadelphia were provided by Mr. Alan F. Trachtenberg, Assistant Director, Air Management Services, Philadelphia Department of Health. Mr. Hashu Shah of the Pennsylvania Bureau of Air Quality and Noise Control, Division of Technical Services and Monitoring, made available data from the other counties in the Philadelphia SMSA.

Although a large amount of valuable air pollution data was gathered with this survey much of the information on solid waste was of low quality. Data from the air management survey was used selectively and included in the sample only when the information appeared to be valid and the other surveys had only a small sample of firms for the particular sector. Nevertheless, this survey included valuable data for many firms that would otherwise have been unavailable.

The Regional Science Research Institute Supplementary Survey

A limited survey of manufacturing firms was conducted by the Regional Science Research Institute in order to supplement the information available from the two sources mentioned above. The following criteria were used to select the sample of firms.

1. Firms in sectors for which the data collected previously included a small number of establishments or insufficient information on waste generation were contacted. In some cases, it was necessary to solicit data from firms outside the Philadelphia SMSA to produce an adequate sample.

2. Large firms not included in the Pennsylvania Solid Waste or Air Management Surveys were mailed questionnaires.

Table 1
REGIONAL SCIENCE RESEARCH INSTITUTE SOLID WASTE SURVEY
RESPONSE RATE, BY TWO-DIGIT SIC GROUPS

<u>SIC Group</u>	<u>Number of Four-Digit Sectors Covered</u>	<u>Number of Questionnaires Sent</u>	<u>Number of Questionnaires Received</u>	<u>Response Rate (%)</u>
20	33	149	55	37
21	1	2	1	50
22	27	187	36	19
23	33	103	25	24
24	9	46	13	28
25	12	48	13	27
26	14	65	19	29
27	15	57	22	39
28	21	69	24	35
29	4	21	13	62
30	5	23	11	48
31	8	18	5	28
32	18	76	25	33
33	20	65	18	28
34	24	135	40	30
35	36	154	51	33
36	28	114	23	20
37	12	69	9	13
38	9	27	8	30
39	18	37	7	19
Total	347	1,465	418	29

3. If the data received from an important firm in the other surveys was suspected to be incomplete or unreliable, that firm was included.

4. A particular effort was made to include information from establishments in the three New Jersey counties that are a part of the Philadelphia SMSA and were not covered by the two surveys conducted in Pennsylvania.

Industrial directories were used to identify the firms to be surveyed. A phone call was made to each firm in order to ascertain the person best able to answer questions about the firm's solid waste, usually the plant manager. Questionnaires were addressed directly to these people. A copy of the questionnaire and explanatory letters sent to the firms is included as Appendix A. Several weeks after the questionnaires were sent, follow-up telephone calls were made to firms that had not responded and respondents were sometimes contacted again to clarify information that they supplied.

The results of the supplementary survey are summarized in Table 1. 1465 questionnaires were mailed and 418 replies were received, a response rate of almost 30 per cent. Data from the other sources compensated for low response rates in several industries. The supplementary survey yielded much of the best data that was included in the total sample.

Sample Coverage

Data from the Pennsylvania Industrial Solid Waste Inventory, the Pennsylvania Air Management Inventory, and the Regional Science Research Institute Supplementary Survey were combined to form the total sample used in calculating the solid waste coefficients. This was necessary because of the difficulties involved in getting reliable information on waste generation and the desirability of having a large data base. Care was taken to avoid errors due to changes in the products or capacities of the firms between the dates of the various surveys.

Tables 2 and 3 summarize the industry coverage of the sample. Of the 424 four-digit manufacturing sectors listed in the 1967 SIC manual, 378 industries, or 89 per cent, were identified in the Philadelphia SMSA in 1967 (Isard, et al. [1967]). Information on solid waste generation was obtained for 342 industries, or more than 90 per cent of the manufacturing activities in the Philadelphia economy. Information on three or more firms was obtained in 247 four-digit sectors, or on more than 65 per cent of the industrial sectors covered. (See Table 2). No data on waste generation could be obtained for 36 four-digit sectors, and data from only one firm were available for another 45 sectors. For the most part, however, these were the small or declining industries in the region.

Table 2

NUMBER OF FOUR-DIGIT MANUFACTURING INDUSTRIAL SECTORS IN PHILADELPHIA
REGIONAL ECONOMY AND IN SAMPLE, BY TWO-DIGIT INDUSTRY GROUPS

Number of 4-digit Industrial Sectors								
SIC Group	In SIC Manual	In Phila. SMSA '68*	In Sample					Not in Sample
			Total	Size of 4-digit sample**				
				1	2	3	4+	
20	45	37	33	4	8	6	15	4
21	4	3	1	1	-	-	-	2
22	29	28	27	1	4	4	18	1
23	33	33	31	3	2	2	24	2
24	13	10	7	1	2	-	4	3
25	12	12	12	1	1	1	9	-
26	16	14	14	1	-	1	12	-
27	16	16	15	-	-	3	12	1
28	31	25	19	1	3	1	14	6
29	5	4	4	-	-	-	4	-
30	5	5	4	-	1	1	2	1
31	10	9	8	1	3	1	3	1
32	27	24	24	6	6	2	10	-
33	24	21	19	4	3	2	10	2
34	27	26	26	3	2	2	19	-
35	40	37	35	5	2	6	22	2
36	33	28	27	6	8	3	10	1
37	16	12	10	3	2	1	4	2
38	11	9	8	-	1	1	6	1
39	27	25	18	4	2	2	10	7
Total	424	378	342	45	50	39	208	36
Per cent		100.0	90.5	11.9	13.2	10.3	55.0	9.5

* Isard, Langford, & Romanoff [1967].

** Number of complete returns for a given 4-digit industry group.

Table 3
EMPLOYMENT OF REPORTING ESTABLISHMENTS AND SAMPLE COVERAGE,
SUMMARY BY TWO-DIGIT SIC GROUPS

SIC Group	Phila. SMSA Total		Sample		Sample as Percent of SMSA	
	Firms	Empl.	Firms	Empl.	Firms	Empl.
20	599	48,522	209	29,537	35	61
21	10	1,569	1	1,300	10	83
22	335	25,619	174	15,803	52	62
23	698	52,937	275	28,352	39	54
24	162	2,301	53	1,086	33	47
25	232	7,572	81	4,806	35	63
26	245	22,764	95	12,209	39	54
27	1,014	38,160	249	20,718	25	54
28	357	36,468	151	27,376	42	75
29	49	12,158	21	9,323	43	77
30	198	15,830	72	11,922	36	75
31	52	2,265	25	1,445	48	64
32	274	14,069	84	8,364	31	59
33	166	35,590	80	21,223	48	60
34	891	37,887	288	22,774	32	60
35	939	59,369	329	38,051	35	68
36	375	59,250	135	25,448	36	43
37	100	42,148	37	23,923	37	57
38	166	17,622	62	11,534	37	65
39	285	8,397	119	4,742	42	56
Total	7,132	537,403	2,540	319,931	36	60

In all, information on solid waste generation was obtained for 2540 establishments, which account for 36 per cent of the manufacturing establishments in the region and 60 per cent of regional employment as of 1968 (see Table 3). The sample included at least 40 per cent of the 1968 estimated regional employment in every two-digit SIC group.

Some Comments on the Collection of Information on Solid Waste

Several observations about the difficulties involved in collecting information related to environmental issues are relevant to the data gathered in this study.

A. Cooperation

A large number of firms were cooperative in supplying information as the results of the Regional Science Research Institute survey indicates, and many of the businessmen contacted expressed concern over environmental problems. The data collection effort was not without difficulty, however. Many firms were reluctant to respond to our questionnaire. Some of the firms were hesitant to disclose information of any kind and complained of being sent too many questionnaires. Firms that sold scrap material were sometimes reluctant to give out information about their scrap sales. Fears of additional environmental controls by government were commonly expressed. Solid waste is not as delicate an issue as air or water pollution. On the other hand, pollution emissions must be measured, so that what information is obtained is likely to be more accurate than information on waste generation, which generally is derived from estimation rather than from measurement.

We had expected that plant managers or others familiar with the operations would be capable of giving reasonably accurate es-

timates of waste generation even if no records were kept on waste disposal. This was frequently not the case. It was not unusual to talk with people who were willing to cooperate with the study but just didn't know the quantity or types of waste generated by their firms. Not surprisingly, waste generation is of very little concern to most businessmen, and disposal costs are simply considered a normal business expense. Responses sometimes included estimates of the total amount of waste generated but little information about the kinds of material in the refuse.

One might anticipate a tendency to underestimate the quantity of wastes generated. Some respondents, however, appeared to overestimate the amount of solid waste reported (or perhaps underreported employment) so that it is difficult to uncover any consistent bias in the data.

Large firms responded more frequently and answered the questionnaire with more detail than did smaller establishments. Many large businesses had done studies of their solid waste problems and the requested information was readily available. In some cases, these firms had engineers or other staff members working exclusively on environmental problems. Data from actual measurements were usually not available from smaller firms which responded more often by supplying estimates of waste generation. Managers of very small

firms were most likely to have a comprehensive knowledge of their operations, however, and could often give accurate estimates. Medium sized firms were the most difficult group to survey.

B. Procedures

Efforts were made in collecting and handling the data to compensate for the problems encountered in data collection. The questionnaire for the supplementary survey was designed to get the maximum amount of useful information from the respondents (see Appendix A). Two questions were included that could be used to estimate the amount of solid waste generated by the firm. Information on the size and number of containers used for refuse removal was requested in Question 4. Question 5 asked for a detailed breakdown of waste quantities by type of material. Many of those how could not estimate waste quantities could give good information on container sizes and frequency of removal from which waste generation estimates might be made. If detailed information was given for both questions, an internal check on the accuracy of the estimates was possible.

Specifying the quantity of various different materials generated as waste was particularly difficult for some firms. The questionnaire allowed the firms to estimate the percentage of various materials included in the total waste quantity if the exact

breakdown was not known. Sometimes there was difficulty determining even percentages, however.

The respondent had the option of indicating either the weight or volume of solid waste. Weight estimates were precise for materials sold as scrap but unreliable for wastes requiring disposal. Firms found it easier to estimate waste quantity in volume when no records were available.

A set of volume to weight conversion factors was developed and is presented in Appendix D. Since the weight of materials found in refuse varies according to compaction, porosity, moisture content, and other variables, it is impossible to give exact volume to weight figures. The conversion factors are based on the best available information from a variety of sources and are intended as rule-of-thumb guides. They were used only when weight information was not available or was clearly inferior to volume estimates and then only after obtaining as much information as possible about the materials under consideration.

The possibility of firms supplying inaccurate or incomplete information was taken into account in processing the data. An attempt was made to obtain large samples in each sector and consistencies in reported waste generation rates for different

establishments were sought. Obviously ridiculous responses were omitted from the sample. Since only the best responses included detailed breakdowns of the types of material and estimates of materials that occur in small quantities, procedures for calculating the coefficients were designed to allow the use of even partially complete responses (see Appendix E).

Analysis

Input-output methods have proven useful in a variety of applications. Reliable information on solid waste, however, is more difficult to collect than data on the cost of inputs used in conventional input-output analysis. Therefore, it is important to demonstrate the accuracy of the solid waste coefficients. In this section, the internal consistency of the solid waste data is examined and the coefficients are compared to conventional input-output coefficients and solid waste information from other studies in order to assess their usefulness in predicting waste generation.

A. Level of Industrial Aggregation

Waste generation coefficients were calculated as weighted averages of information of a sample of firms in each four-digit sector. The logic behind dividing the firms into detailed industrial categories is that firms producing similar products and using similar technology should exhibit similar waste generation characteristics. Waste generation rates, of course, may vary because of differences in products, processes, technical efficiency, economies of scale, and other factors for firms in the same industry. Nevertheless, if input-output methods are to be useful and if the data collected on waste generation is valid, there should be less variation between firms in the same industrial category than between

firms in different industrial categories.

The level of aggregation of industrial categories may have a significant effect on the reliability of the coefficients, since industrial mix problems are expected to become more troublesome as industries are aggregated. If waste generation rates for firms within a sector are different because firms producing a variety of products are classified in the same group, the coefficients will have large variances and predictions will be accurate only within wide ranges. The use of the coefficients to predict waste generation in future periods or for other regions requires the assumption that industrial mix does not vary over time or between regions. On the other hand, disaggregation may result in accentuating inaccuracies in the data by having small samples for many sectors. For this reason, the results of analyzing the data at different levels of aggregation are compared.

An analysis of variance techniques (Freund [1962]) was applied in evaluating the internal consistency in the solid waste data and determining the optimal level of disaggregation for accurate prediction.¹⁰ The total amount of variation in the data for any

¹⁰The actual analysis of variance test requires the assumption that the population from which the sample was drawn is normally distributed. This is questionable for data on waste generation (see Combustion Engineering [1970]). Also, the fact that the coefficients are weighted averages changes the interpretation of the test statistic. For these reasons, the actual analysis of variance tests are not presented here. The tests applied to the waste generation data, however, indicate that the four-digit classification explains a significant proportion of variance in most of the industries.

two-digit SIC group may be partitioned into the variation between firms within the four-digit sectors and the proportion of variation accounted for by dividing the industry into four-digit categories.

$$\sum_i \sum_j E_{ij} (X_{ij} - \bar{\bar{X}})^2 = \sum_i \sum_j E_{ij} (X_{ij} - \bar{X}_i)^2 + \sum_i E_i (\bar{X}_i - \bar{\bar{X}})^2$$

where: E_{ij} = the employment for firm j in four-digit sector i ,

E_i = the total employment in the sample for four-digit sector i ,

X_{ij} = tons of waste generated per employee per year for firm j in sector i ,

$\bar{X}_i$ = the average waste per employee coefficient for four-digit sector i , and

$\bar{\bar{X}}$ = the average waste-per-employee coefficient for the entire two-digit industry.

The difference between the average amount of waste generated per employee for the entire sample and the waste per employee figure for each firm is calculated. The sum of these deviations weighted by the employment for each firm represents the total amount of variation in the data for the entire industry and is shown on the left of the equation.

Total variation is partitioned into two components. The second term on the right of the equation is the summation of squared deviation of the average waste per employee for each four-digit sector

around the average coefficient for the industry, each deviation being weighted by the number of employees in the sample for each sector. This term measures the amount of variation in two-digit industry explained by dividing the two-digit industry into four-digit categories.

The amount of variation within the four-digit sectors is given by the first term to the right of the equality sign. This is the weighted sum of squared deviations of the waste per employee figures for each firm around the mean coefficients for their respective (four-digit) sectors.

Table 4 summarizes the results of this analysis applied across the entire range of manufacturing industries. At the two-digit-level, the variation around a single average waste generation factor is compared to the sum of squared deviations around the twenty two-digit waste per employee coefficients. Less than 18 per cent of the variation between reporting firms is removed by grouping them into two-digit categories. An additional 34 per cent of the variation is accounted for by disaggregating further to the three-digit level. In going from three to four-digit industries, another 30.5 per cent of the total variation is explained. At the four-digit level more than 80 per cent of the variation in the data is accounted for by the industrial categories with 18 per cent of

unexplained variation remaining between firms within four-digit groups.

A similar evaluation was done for each two-digit manufacturing sector individually. The results are shown in Table 5. Disaggregation to four-digit sectors accounts for more than 50 per cent of the variation in total waste generation per employee for 10 of the 20 two-digit groups. In six of these industries, more than 70 per cent of the variation may be removed by disaggregation. For 7 of the remaining 10 groups, disaggregation explains over 30 per cent of the variance within two-digit industries.

Disaggregation was particularly effective for the Wood (SIC 24), Stone, Clay, and Glass (SIC 32), Transportation and Chemical (SIC 28) industries. The Tobacco industry (SIC 21) was represented by only one four-digit sector in the sample. Printing and Publishing (SIC 27) consists of a number of sectors with relatively low waste generation, similar waste generation characteristics (small differences between sectors), and consequently a low percentage of explained variance at the four-digit level. In this case, disaggregation may be unnecessary.

The Petroleum industry (SIC 29) also had a small percentage of explained variance. Good information was available from firms in this industry and differences in waste generation rates were

evident. However, the coefficients for four-digit industries had large variances. Firms in this industry produce a wide variety of products and use different processes. Additional investigation and perhaps further disaggregation is indicated here.

Table 4
COMPARISON OF EXPLAINED VARIANCE AT DIFFERENT LEVELS OF
AGGREGATION, PHILADELPHIA MANUFACTURING, 1968

<u>Source of Variation</u>	<u>% of Total Variance</u>	<u>Cumulative % of Total Variance</u>
Between two-digit means	17.5	17.5
Between three-digit means	34.0	51.5
Between four-digit means	30.5	82.0
Unexplained within four-digit sectors	18.0	100.0

Several conclusions may be drawn from this analysis. First of all, in spite of questions that were raised about the validity of the information that could be collected in the surveys of industrial establishments, the data exhibits an impressive amount of internal consistency. Similarities reported in waste generation rates for establishments within given industrial categories are much stronger than differences between establishments in the same

industrial categories. Secondly, the SIC categories appear to be a useful way of classifying firms with respect to waste generation. SIC groups differentiate firms on the basis of final product with some additional distinctions by major inputs and processes. As hypothesized, the type of products produced by an establishment appears to be the major determinant of waste generation characteristics.

Finally, the analysis suggests that disaggregation to the four-digit SIC level is worthwhile. Dividing industry into two-digit categories does not seem to be much preferable to using cruder methods such as an extrapolation of trends in the relationship between waste generation and overall economic activity. Large gains in accuracy are possible by disaggregating to the four-digit level. Since only 18 per cent of the variation between firms remains unexplained within four-digit sectors, additional disaggregation of industrial sectors should not prove particularly rewarding. As mentioned previously, a certain amount of variance is caused by factors other than industry classification such as the accuracy of reported estimates, economies of large scale production and differences in technology. This conclusion should not preclude further disaggregation or detail in certain specific industries, however. Also, more detailed industrial categories might be de-

Table 5

PROPORTION OF TOTAL VARIANCE EXPLAINED FOR TOTAL
EMPLOYEE COEFFICIENTS AT FOUR- AND THREE-DIGIT LEVELS
SUMMARIZED BY TWO DIGIT GROUPS, PHILADELPHIA MANUFACTURING

<u>Group</u>	<u>Four-Digit Level</u>		<u>Three-Digit Level</u>	
	<u>Number of Sectors</u>	<u>% of Variance Explained</u>	<u>Number of Sectors</u>	<u>% of Variance Explained</u>
20	33	73.2	9	42.1
21	1	---	1	---
22	27	48.1	9	34.2
23	31	38.6	9	39.5
24	7	93.6	4	90.8
25	12	54.9	5	24.4
26	14	30.2	4	11.8
27	15	8.8	9	5.2
28	19	80.3	7	35.3
29	4	17.3	3	16.6
30	4	32.4	4	32.4
31	8	58.3	6	38.4
32	24	96.0	9	44.1
33	19	42.1	7	27.6
34	26	58.0	9	23.2
35	35	37.2	9	22.6
36	27	36.0	8	12.2
37	10	90.5	4	5.6
38	8	50.7	5	20.5
39	18	92.0	5	8.1
Total	342	80.2	126	51.5

sirable in future studies in which larger samples and more precise information on waste generation could be obtained.

B. Variance

Variance in waste generation coefficients for different sectors may be compared when they are expressed in relative terms. Therefore, coefficients of variation¹¹ for total waste generation per employee were calculated for all two-, three-, and four-digit manufacturing sectors having samples of two or more firms. The results are summarized in Table 6, which shows the average coefficients of variation within two-digit groups at various levels of aggregation.

The average coefficient of variation for 296 four-digit sectors is .490. That is, the variance is 49 per cent of the mean. The statistic ranges from .296 for the Transportation Equipment industry to .605 in the Primary Metals group. When the data are aggregated into three-digit SIC groups, the overall variation increases to an average of .635 (computed over 123 three-digit sectors). Coefficients of variation at the three-digit level range from a low

¹¹ The coefficient of variation is the standard deviation divided by the mean. A listing of average total waste per employee coefficients and standard deviations by four-digit SIC categories calculated using the Philadelphia SMSA waste generation data is included in Appendix F.

Table 6

COEFFICIENTS OF VARIATION FOR TOTAL WASTE PER EMPLOYEE COEFFICIENTS
AGGREGATED AT FOUR, THREE, AND TWO DIGIT LEVELS AND SUMMARIZED BY
TWO DIGIT SIC PHILADELPHIA MANUFACTURING 1968

<u>SIC Number</u>	<u>Four Digit Level</u>		<u>Three Digit Level</u>		<u>Two Digit Level</u>
	<u>Average Coeffi- cient of Variation</u>	<u>Number of Four-Digit Industries</u>	<u>Average Coeffi- cient of Variation</u>	<u>Number of Three-Digit Industries</u>	<u>Average Coefficient of Variation</u>
20	.453	28	.764	1	1.087
22	.431	26	.578	9	.796
23	.467	28	.606	9	.845
24	.453	6	.523	4	2.140
25	.496	11	.530	5	.850
26	.560	13	.607	4	.764
27	.517	15	.519	9	.673
28	.564	18	.801	7	1.834
29	.545	4	.568	3	.616
30	.459	4	.459	4	.655
31	.404	7	.526	5	.561
32	.492	18	.873	8	2.187
33	.605	15	.942	7	.974
34	.584	23	.686	9	.837
35	.525	30	.654	9	.812
36	.356	21	.517	8	.548
37	.296	7	.410	4	.724
38	.476	8	.520	5	.554
39	.523	14	.999	5	1.494
Total	.490	296	.635	123	.997

of .41 again for the Transportation sectors, to a high of .99 for Miscellaneous Manufacturing. At the two digit level, variation ranges from .548 for the Electrical Machinery sectors to 2.187 for the Stone, Clay, Glass and Concrete industry. The average coefficient of variation across all industries once more increases to .997. As can be seen by reading across the rows of Table 4, coefficients of variation for all industry groups increase, without exception, as more aggregated industrial sectors are formed. This supports the hypothesis that industrial mix problems cause the coefficients to be less precise at higher levels of aggregation.

The industries exhibit similar ordering of the coefficients of variation at different levels of aggregation. The Transportation, Electrical Machinery, Leather, Lumber, and Rubber industries had the smallest average variation. Those with the largest variation included: Primary Metals, Chemicals, Paper, Machinery, and Miscellaneous Manufacturing.

These results compare favorably with similar evaluations of conventional input-output data. In the Philadelphia input-output table, the average coefficient of variation for total material inputs calculated over 126 four-digit manufacturing industries was 30.8 per cent. Variation for the largest material input averaged

43.1 per cent.¹²

C. Comparison with Previous Studies

The coefficients developed for Philadelphia may also be evaluated by comparing them with results found in other studies. In view of the large variation associated with waste generation coefficients at the two-digit level of aggregation comparisons were not made with previously published data.

Estimates of waste generation rates for manufacturing industries at the four-digit SIC level are available from unpublished solid waste surveys done in Texas and Kentucky.¹³ The Kentucky

¹² The following results were found by Karaska [1967] in examining the coefficients of variation for input coefficients in the Philadelphia input-output table:

<u>Total Material Inputs</u>	<u>Number of Sectors</u>	<u>Average</u>	<u>Low</u>	<u>High</u>
Four digit	126	.308	.116	.558
Three digit	96	.365	.175	.631
Two digit	20	.451	.223	.637
<u>Largest Valued Input</u>				
Four digit	126	.431	.170	.630
Three digit	96	.508	.338	.507
Two digit	20	.792	.504	1.081

¹³ Printouts of the results of the Texas and Kentucky Solid Waste surveys were supplied by Mr. Ron Talley and Mr. Dan Greathouse of the Environmental Protection Agency.

data included only about 100 four-digit manufacturing sectors. A larger range of industries was covered by the Texas survey (323 four-digit manufacturing sectors), but many industries were represented by small samples. Almost 70 per cent of the four-digit sectors in the Texas survey had sample sizes of only one or two firms.¹⁴ Although neither study is entirely adequate, they were used to fill in gaps and upgrade the data available for Philadelphia in order to develop the set of "best choice" coefficients displayed in Appendix G. The surveys are also useful in analyzing the reliability of the Philadelphia coefficients and determining the importance of regional differences in waste generation characteristics.

Regional differences in industrial mix can be expected to produce differences in waste generation. Dissimilarities of this type were, in fact, apparent in a number of cases. For example, the sample for Canned Fruits and Vegetables (SIC 2033) is dominated by the large mushroom canning industries in the Philadelphia area. Variance of the coefficient for this sector may be accounted for by the fact that several firms producing quite different canned products are also classified in the same sector. The mushroom

¹⁴ Approximately 25 per cent of the four-digit sectors covered by the Philadelphia sample were represented by fewer than three firms.

industry, with its high waste generation, is unique to Philadelphia and the smaller coefficient from the Texas survey represents a different industrial mix.

Bag Manufacturing (SIC 2634) is a second example. This category includes firms producing both plastic and paper bags. In the data gathered for the Philadelphia SMSA, it was evident from the amounts and types of refuse generated which products each firm produced. Again the standard deviation for the Philadelphia sample was high and the coefficients for Texas and Philadelphia differed substantially because of different industrial mixes for the two regions.

Coefficients from different regions should be similar aside from variation due to industrial mix, however. At the four-digit level of aggregation, industrial sectors are relatively homogeneous, and some consistency in waste generation is necessary for input-output techniques to be applicable. Table 7 shows correlation coefficients between average total waste per employee for four-digit sectors in Philadelphia and Texas. The correlation for 274 sectors in which results could be compared is .49, which indicates a great deal of agreement in the results of the two studies.

Table 7
CORRELATIONS BETWEEN PHILADELPHIA AND TEXAS COEFFICIENTS OF AVERAGE
TOTAL WASTE PER EMPLOYEE, FOR FOUR-DIGIT INDUSTRIES

SIC SIC Group	Number of Four-Digit Sectors	Coefficient of Correlation
20	25	.559
21	0	---
22	14	.146
23	24	.349
24	7	.988
25	11	.396
26	11	.792
27	14	.128
28	16	-.016
29	4	.404
30	2	---
31	8	.463
32	23	.001
33	16	.166
34	21	.438
35	27	.303
36	21	.228
37	9	.315
38	7	.601
39	14	.213
Total	274	.487
Large Samples*	88	.601

*Sectors for which both the Philadelphia and Texas samples included four or more firms.

As mentioned, the Texas survey contained many small samples. Small sample size was also unavoidable for some sectors in the Philadelphia sample. Since a small sample is unlikely to reflect the true range of waste generation characteristics for many sectors, one would expect more similarity between coefficients found for Texas and Philadelphia in industries for which large samples could be obtained. Both the Texas and Philadelphia samples included three or more firms in 88 sectors. The coefficient of correlation in these sectors was .60.

Waste generation rates in Texas and Philadelphia were strongly correlated for firms in the Food (SIC 20), Technical Instruments (SIC 38), Paper (SIC 26), and Lumber (SIC 24) industries. Little correlation was evident in Chemicals (SIC 28), Stone, Clay, and Glass (SIC 32), Printing (SIC 27), Textiles (SIC 22), and Primary Metals (SIC 33). Since these are all industries that produce diversified outputs, regional variations in industrial mix at four-digit level rather than differences in waste generation might be the cause of the low correlations.

The general similarity between the Philadelphia and Texas data indicated by the correlation coefficients must be qualified. A significant, positive correlation implies only that sectors with

high waste generation rates in the Philadelphia sample tend also to have large coefficients in the Texas data and sectors with low waste generation also coincide. This does not preclude a systematic difference in the magnitude of the coefficients, which seems to be the case.

The Philadelphia coefficients tend to be consistently larger than the Texas coefficients. This may be demonstrated by a simple test. The coefficients were directly compared and divided into four categories depending on whether, for each four-digit SIC category, the Philadelphia waste generation coefficient was greater or less than the Texas coefficient and whether one of the coefficients was more than twice as great as the other. Of 280 four-digit sectors that could be compared, the Philadelphia coefficients were larger than Texas in 203 cases and more than half the Philadelphia coefficients were more than twice as large as their counterparts in the Texas data. The observed distribution is significantly different from a hypothetical distribution based on what might be expected in the case of two similar sets of data (75 per cent of the comparisons differ by less than a factor of two).

Further insight into the differences between the Texas and Philadelphia data may be gained from Table 9 which compares the frequency distributions for the two sets of coefficients. A much

Table 8

DIRECT COMPARISON OF PHILADELPHIA AND TEXAS TOTAL SOLID WASTE
GENERATION COEFFICIENTS, BY FOUR DIGIT SIC CLASSIFICATION

	<u>No. of Four-Digit Industry Groups</u>	
	<u>Observed</u>	<u>Expected</u>
Philadelphia Coefficient is:		
greater than twice Texas Coefficient	147	35
greater than Texas but less than twice Texas Coeffi- cient	56	105
less than Texas, but greater than one-half Texas Co- efficient	38	105
less than one-half Texas Coefficient	39	35
Total no. Four-Digit Coefficient	280	280

$$\chi^2 = 424.5$$

$$\chi^2_{.01, 3} = 11.34$$

larger proportion of the Texas coefficients are very small. A suspected bias on the part of firms to underestimate waste generation has been mentioned previously. The preponderance of very small samples used to calculate the Texas coefficients may have accentuated errors caused by unreliable responses. This, rather than interregional variation in waste generation, might explain the systematic differences that exist between the two sets of coefficients in spite of the significant correlations.

Table 9
COMPARISON OF FREQUENCY DISTRIBUTIONS, PHILADELPHIA AND TEXAS
WASTE GENERATION COEFFICIENTS

Range of Coef. (tons/empl/yr)	<u>Philadelphia</u>			<u>Texas</u>	
	<u>No. of 4-Digit Industries</u>	<u>%</u>	<u>% of Total Empl.</u>	<u>No. of 4-Digit Industries</u>	<u>%</u>
0-2	130	38.0	39.4	204	63.2
2-4	109	31.9	29.5	44	13.6
4-6	36	10.5	10.1	15	4.6
6-8	14	4.1	3.6	6	1.9
8-10	5	1.5	1.3	8	2.5
10-12	14	4.1	4.5	8	2.5
12-14	8	2.3	4.7	2	.6
14+	26	7.6	6.7	36	11.2
TOTAL	342	100.0	100.0	232	100.0

Summary

Solid waste generation coefficients for 342 four-digit SIC manufacturing industries are presented in this paper. The coefficients are based on information collected from a large sample of industrial establishments in the Philadelphia area and specify waste generation rates in tons per employee per year for fourteen categories of materials. Analysis indicates that significantly less variation in total waste generation rates exists for firms within four-digit SIC groups than between groups. Less internal consistency is evident as the data are aggregated to three and two-digit SIC groups. The variances of the waste generation coefficients are in the same order of magnitude as those for conventional input-output coefficients.

This study indicates somewhat more waste generation per worker than do previous detailed studies. Reliance may be placed on these results because of the care with which responses of individual firms were evaluated, and the generally larger sample sizes attained in this study. Our results suggest the desirability and usefulness of detailed environmental coefficients for environmental planning.

Bibliography

1. American Institute of Steel Construction, Manual of Steel Construction (Sixth Edition), 1964.
2. American Public Works Association, Municipal Refuse Disposal, Public Administration Service, Chicago, 1966.
3. Ayres, L., I. Gutmanis and A. Shapanka. Environmental Implications of Technological and Economic Change for the United States, 1967-2000: An Input-Output Analysis. Report prepared for Resources for the Future, Inc., International Research and Technology Corp., Washington, D.C., June 1971.
4. Ayres, R. V. and A. V. Knesse. "Production, Consumption and Externalities," American Economic Review, Vol. 59, June 1969.
5. Bucciarelli, W. "The Pennsylvania Solid Waste Management Program" in Proceedings of the 25th Industrial Waste Conference, May 5, 6, and 7, 1970 (Part 2). Purdue University, Lafayette, Indiana, Engineering Extension Series No. 137, Engineering Bulletin.
6. Camp, Dresser and McKee. Erie and Niagara Counties Comprehensive Solid Waste Study, New York, State Department of Environmental Conservation and Erie and Niagara Counties Regional Planning Board, June 1972.
7. Combustion Engineering, Inc., Windsor, Connecticut. Technical-Economic Study of Solid Waste Disposal Needs and Practices, Public Health Service Publication No. 1886, Washington, U.S. Government Printing Office, 1970.
8. Council on Environmental Quality, Environmental Quality: The First Annual Report of the Council on Environmental Quality, Washington, U.S. Government Printing Office, 1970.
9. Commonwealth of Pennsylvania, Department of Commerce. 1970 Industrial Directory of the Commonwealth of Pennsylvania (19th Edition), Harrisburg, Bureau of Statistics, 1970.
10. Commonwealth of Pennsylvania, Department of Health. A Plan for Solid Waste Management in Pennsylvania, Bureau of Housing and Environmental Control, Harrisburg, 1970.

11. Cumberland, J. H. and B. N. Stram. "Economic Flows and Environmental Coefficients," Review of Regional Studies, Vol. II, No. 3, Spring 1972, pp. 28-40.
12. Darnay, A. and W. E. Franklin. The Role of Packaging in Solid Waste Management, 1966 to 1967, Public Health Service Publication No. 1885. Washington, U.S. Government Printing Office, 1969.
13. Freund, J. E. Mathematical Statistics, Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 1962.
14. Golueke, C. G. and P. H. McGauhey. Comprehensive Studies of Solid Waste Management; First and Second Annual Reports, Public Health Service Publication No. 2039, Washington, U.S. Government Printing Office, 1970.
15. 1969 Greater Philadelphia Industrial Directory, Dalton Corporation, Philadelphia, 1969.
16. Hite, J. and E. A. Laurent. "Empirical Study of Economic-Ecological Linkages in a Coastal Area," Water Resources Research, Vol. 7(5), October 1971, pp. 1070-1078.
17. Institute of Scrap Iron and Steel, Inc. Facts, 31st Edition Yearbook, 1970.
18. Isard, W., T. W. Langford, Jr., and E. Romanoff. Philadelphia Region Input-Output Study, Working Papers, Department of Regional Science, University of Pennsylvania and Regional Science Research Institute, Philadelphia, 1967.
19. Isard, W., C. L. Choguill, J. Kissin, R. H. Seyfarth, R. Tatlock, etc. Ecological-Economic Analysis for Regional Development, The Free Press, New York, 1972.
20. Karaska, G. J. "Variation of Input-Output Coefficients for Philadelphia Manufacturing," RSRI Discussion Paper Series: No. 13, Philadelphia, 1967.
21. Kinney, G. F. Engineering Properties and Applications of Plastics, John Wiley and Sons, New York, 1957.

22. Leontief, W. "Environmental Repercussions and Economic Structure: An Input-Output Approach," Review of Economics and Statistics, Vol. 52, August 1970, pp. 262-271.
23. Oregon State Board of Health. Industrial Solid Waste Survey, Oregon, 1970.
24. Pettigrew, R. J., F. H. Roninger, W. H. Markiewicz, and M. J. Gransky. Rubber Reuse and Solid Waste Management, Public Health Service Publication No. 2124, Washington, U.S. Government Printing Office, 1971.
25. Romanoff, E. "Material Reclamation Industries in Regional Economies," Paper presented at the 1972 IEEE Conference on Decision and Control, New Orleans, La., December 1972, Regional Science Research Center, Cambridge, Mass., September 1972.
26. Steiker, G. "Application of Input-Output Techniques to Solid Waste Problems" RSRI Discussion Paper Series, forthcoming 1974.
27. U.S. Bureau of the Budget, Standard Industrial Classification Manual, Washington, U.S. Government Printing Office, 1967.

Appendix A

QUESTIONNAIRE AND INTRODUCTORY LETTERS:
SUPPLEMENTARY SURVEY

Dear Sir:

As part of our current research project on the economics of solid waste disposal and recycling, the Regional Science Research Institute is conducting a questionnaire survey of industrial establishments. The survey results will provide basic data which will be useful for coping with the solid waste problem throughout the country as well as in Philadelphia.

The success of the study depends on your cooperation as well as that of many other firms. A questionnaire which we request you to complete and return to us is enclosed. Recognizing the value of your time, we have tried to make the questionnaire as short as possible. The information you provide will be kept in strict confidence and no data will be published that would reveal information on individual firms.

If you have any questions regarding the study or the questionnaire, we will be pleased to assist you in any way possible. Please call Mr. Gene Steiker at BA 2-3940. Also enclosed is a letter from Mr. Thacher Longstreth, President of the Greater Philadelphia Chamber of Commerce, indicating his interest in the study.

Thank you for your kind cooperation. If you would like a summary of the results of our survey, please indicate this on your response.

Sincerely yours,

Dr. Robert Coughlin
Vice President



Greater PHILADELPHIA CHAMBER OF COMMERCE

1838 WALNUT STREET • PHILADELPHIA, PA. 19102 • TELEPHONE 735-9820 (AREA CODE 215)

The Regional Science Research Institute, a private non-profit organization, is conducting a program of basic research on the economics of solid waste disposal and recycling. The results of this study will be useful to business groups and governmental bodies for projecting the demand for waste disposal services, evaluating systems for the more efficient disposal of refuse, and analyzing new ideas for the reuse of scrap materials.

Despite the current concern about the growing problems of solid waste disposal, very little is known about what types of waste and how much is produced by specific economic activities or how the materials are disposed of or recycled. The Regional Science Research Institute study is designed to fill this gap in knowledge. In order to obtain this information, the enclosed questionnaire is being sent to you and to other firms which constitute a carefully selected sample of the economy of the Philadelphia region.

I would therefore greatly appreciate it if you could cooperate with the Institute's study in supplying the information that they request. You may rest assured that whatever information you provide will be kept in the strictest confidence and no data will be published which would reveal information on individual firms.

Sincerely yours,

Thacher Longstreth
President

Regional Science Research Institute Solid Waste Study Industrial Survey

Please complete this questionnaire
and mail to:

Solid Waste Study
Regional Science Research Institute
G.P.O. Box 8776
Philadelphia, Pennsylvania 19101

If any questions arise with
regard to specific items in
this questionnaire, please call:

Mr. Gene Steiker
BA2-3940 or BA2-6540

Information is requested for the calendar year 1971. If it is not
possible to provide data for 1971, please specify the year used.

Please report information for the plant listed below.

-
1. Respondent's name and position:
 2. Type(s) of products manufactured: [Please specify in detail the products produced and the amount of processing done by your firm (example: Women's dresses, cut and sewed from purchased fabric). If you manufacture several products, please list them and indicate which products are the major ones. Also, note activities other than manufacturing, such as retailing and wholesaling, that are carried out at the plant listed if the estimates of waste generation include waste from these activities.]
 3. Average employment: 1971_____, 1968_____.
 4. What type and size containers are used to store solid waste on your premises for disposal by the municipality, waste disposal company, or your employees. Please be specific (examples: 55 gal. drums; boxes 3' x 4' x 3'). Also, how often is the solid waste or refuse removed from your plant and how many containers are taken away (on average) each time refuse is removed?

Type of Container	Number Removed	How often are they removed?
1.		
2.		
3.		

5. Please indicate the amount of each kind of material listed below generated by your firm as refuse or solid waste. If it is not possible to give a detailed breakdown on the amounts of different types of materials, please indicate the total amount of solid waste and, in the column headed "%", estimate the percentage of the total accounted for by each type of material.

[Solid waste or refuse is defined here as any materials other than your finished products that are generated as a result of your firm's operations and that must be removed from your premises. Include any materials that are sold or given away for reuse as scrap materials in these estimates. Do not include materials that are recycled internally by your firm and which do not leave the plant.]

Type of Material	Amount (fill in one)			Per (check one)			%	Explanation: More detailed description of the type of material.
	tons	cu. yds. compacted	cu. yds. uncompact.	year	month	week		
Non-Production Refuse								
1. Office trash								
2. Cafeteria waste								
Production Refuse								
3. Paper								
4. Cardboard								
5. Wood								
6. Rags & textiles								
7. Plastic								
8. Rubber								
9. Glass								
Food processing								
10. waste								
11. Metal:ferrous								
12. Metal:non-ferrous								
Petroleum and								
13. paints								
14. Chemicals								
Soil, sand, and								
15. ashes								
16. Sewage sludge								
Other (specify type)								
17.								
18.								
TOTAL								

6. The information given in Question 5 is (1) estimated _____
(2) from actual records _____

7. Are any of the refuse materials sold or given away to be salvaged (for example, waste paper sold to a broker or ashes given away to be used as fill material)? If so, what materials?

8. Does your firm use any scrap materials as inputs (for example, scrap metal or reclaimed paper)?

9. Was the change in the amount of solid waste generated proportional to the changes in output and employment between 1968 and 1971?

Yes _____ No _____

If no, please explain.

Were different types of materials generated as solid waste in 1968?

Yes _____ No _____

If yes, please explain.

10. Name and address of waste removal company used by your firm.

Appendix B

QUESTIONNAIRE:
PENNSYLVANIA INDUSTRIAL SOLID WASTE INVENTORY

INDUSTRIAL AND AGRICULTURAL SOLID WASTE INVENTORY

DATE

NAME OF ESTABLISHMENT						S.I.C. NO.								
ADDRESS		STREET		CITY, BOROUGH, TOWNSHIP		COUNTY	ZIP CODE							
TYPE(S) OF PRODUCT MANUFACTURED, PRODUCED, PROCESSED, OR SOLD:						PERSON INTERVIEWED								
						POSITION TITLE								
A) TYPE RI FUSE OR SOLID WASTES - Generated or Salvaged as a result of your Operations.		Special Handling Required Yes No		B) Volume Per Year Cu. Yds. Tons		C) Seasonal Nature (Check Activity)					D) Volume Salvaged		EXPLAIN: Any Special Handling Methods or Salvage Comments for each Type Listed	
						1st. Qu.	2nd. Qu.	3rd. Qu.	4th. Qu.	All Year	Salvaged /Year			Cu. Yds.
1.														
2.														
3.														
4.														
5.														
6.														
7.														
METHOD OF TRANSPORTING WASTES						DISPOSAL SITE INFORMATION								
Collection	% Of Total	Name Of Collector	Type Waste	Frequency Wk. Month	Disposal Site	% Of Total	Name and Location Of Site	Type of Waste	Distance In Miles					
MUNICIPALLY COLLECTED					MUNICIPAL INCINERATOR									
PRIVATE CONTRACT					MUNICIPAL LANDFILL									
EMPLOYERS REMOVE TO SITE					MUNICIPAL DUMP									
SALVAGE OPERATION OR CONTRACT		USE:			ON-PREMISE INCINERATION									
TYPE OF COLLECTION VEHICLES (Check)					ON-PREMISE LANDFILL									
☐ Open Truck ☐ Closed Truck ☐ Tank Truck					ON-PREMISE DUMP									
☐ Open Truck (With Tarpaulin) ☐ Compactor Truck					PRIVATELY OWNED LANDFILL									
☐ Other (Specify):					PRIVATELY OWNED DUMP									
COST INFORMATION - EMPLOYEE HANDLING COSTS					COMPOST									
Man-Days Per Month:		Cost Per Month Wages	\$		OTHER (Specify):									
TRANSPORTATION COSTS PER MONTH					SALVAGE OPERA- TION	TYPE OF SALVAGE OPERATION								
DISPOSAL SITE FEE OR CONTRACT FEE PER MONTH														
OTHER COSTS (Specify):														
Total Costs Per Month														

TYPE OF CONTAINER (Check)	Number Of Containers	Volume Of Containers	TYPE OF WASTE	Weight	Volume	Cost
☐ Bulk Containers						
☐ Drums						
☐ Galvanized Containers						
☐ Plastic Containers						
☐ Other:						

Open Storage Check Method	TYPE OF WASTE	Potentially Hazardous	VOLUME	Frequency Of Removal	If Potentially Hazardous, Explain:
☐ On Ground		Yes No			
☐ Other (Specify):					

PROBLEMS RECOGNIZED BY INDUSTRY—COMMENTS REQUESTED

STORAGE AND COLLECTION:

SALVAGE:

Has any research or experimentation been tried by the establishment to increase the salvage potential of wastes? Explain.

DISPOSAL:

1. Is the present disposal method satisfactory? ☐ Yes ☐ No If No, Comment.
2. What suggestions do you have for more economical methods of disposal or better utilization of wastes?

INTERVIEWER'S REMARKS:

DATE COMPLETED:	INTERVIEWER'S NAME	TITLE
-----------------	--------------------	-------

MS-3113 PAGE 2 CONTINUED

Appendix C

QUESTIONNAIRE:
PENNSYLVANIA AIR MANAGEMENT INVENTORY

127

PRIMARY PLANT INFORMATION

FIRM CODE	PLANT CODE	SIC	LOCATION CODE	GEOGRAPHIC CODE	FIRM NAME
2-13	13-13	13-17	13-22	27-41	43-78

FIRM ADDRESS		STREET	CITY	ZIP CODE
FIRM CODE	2-13	13-29	30-48	40-50

NAME & ADDRESS OF OFFICIAL TO BE CONTACTED ON AIR POLLUTION MATTERS

FIRM CODE	INITIAL	LAST NAME	STREET	CITY	ZIP CODE	TEL. A.C.	TELEPHONE NUMBER
2-13	14	13-29	30-48	40-51	40-44	87-60	70-76

GENERAL PLANT OPERATING SCHEDULE

FIRM CODE	SHIFTS	HOURS PER SHIFT	DAYS PER WEEK	DAYS PER YEAR	SEASONAL PERIODS - MONTHS				DOES FIRM HAVE ITS OWN COMBUSTION EQUIPMENT?		DOES FIRM HAVE ITS OWN INCINERATOR?		
					PEAK OPERATING PROCESS	NON-OPERATING BOILER	PROCESS	TO	TO	TO	TO	YES	NO
2-13	14	15-16	17	18-20	21-24	25-28	29-32	33-36	37	37	37	38	38

NATURE OF BUSINESS (cont'd)

INDUSTRY	STATE PRINCIPAL PRODUCT	LAUNDRY AND CLEANING
DOING	MEDICAL	EDUCATIONAL
OTHER	STATE SPECIFIC TYPE	GOVERNMENTAL

PRINCIPAL METHOD OF COMBUSTIBLE REFUSE DISPOSAL	AMOUNT OF NON-COMBUSTIBLE REFUSE GENERATED IN TONS PER YEAR
NOT APPLICABLE 1	SCAVENGER 3
INCINERATOR 2	CITY PICK-UP 4
LAND FILL 5	AMOUNT

CHEMICALS	COAL REFUSE	SALVAGE RECLAMATION	BIOLOGICAL	AMOUNT
BASES	MIXED REFUSE	DRY GOODS	PAINTS AND SOLVENTS	PRINCIPAL METHOD OF NON-COMBUSTIBLE REFUSE DISPOSAL
PAPER AND WOOD PRODUCTS	PLASTIC PRODUCTS	RUBBER PRODUCTS	SCAVENGER 1	NOT APPLICABLE 3
			FILL 2	CITY PICK-UP 4

PERSON PREPARING REPORT (SIGNATURE & TITLE)

DATE

Appendix D

VOLUME-TO-WEIGHT CONVERSION FACTORS

SOLID WASTE DENSITY

<u>Material</u>	<u>Tons per cu. yard</u>	<u>Material</u>	<u>Tons per cu. yard</u>	<u>Material</u>	<u>Tons per cu. yard</u>
<u>PAPER</u> ¹		<u>FOOD</u> ⁷		<u>FERROUS METALS</u> ⁹	
Uncompacted	0.13	Offal, shells	0.50	Cast iron	.61
Compacted	0.38	Vegetable/fruit waste	0.30	Steel	.66
<u>WOOD</u> ²		Chaff	0.05	Cans-uncrushed	.06
Sawdust	0.25	Flour, loose	0.38	Cans-crushed	.56
Bark slabs	0.30	Flour, pressed	0.63		
Wood trimmings	0.50	Salt, granulated, piled	0.65	<u>NON-FERROUS METAL</u> ⁹	
Wood shavings	0.20	Garbage	0.40	Bronze	.68
Pallets (50 lbs. each)	0.15			Copper	.75
Composite	0.35	<u>PETROLEUM</u> ⁸		Lead	.96
<u>RUBBER</u> ³		Paraffine	0.76	Magnesium alloys	.15
Uncompacted	0.25	Petroleum	0.73	Manganese	.64
Compacted	1.02	Petroleum, refined	0.68	Nickel	.76
<u>PLASTIC</u> ⁴		Petroleum, benzine	0.62	Tin	.62
Uncompacted	0.18	Petroleum, gasoline	0.57	Zinc	.59
Compacted	0.54	Pitch	0.93	Brass	.72
Styrofoam	0.02	Tar, bituminous	1.01	Aluminum	.22
<u>GLASS</u> ⁵		Asphaltum	1.09		
Unbroken bottles	0.30	Ink	0.80		
Broken glass	1.00	<u>CHEMICALS</u>			
Crushed glass	2.00	Find as and when required			
<u>TEXTILES</u> ⁶		SOIL, SAND, ASHES			
Uncompacted	0.15	Floor sweepings and general rubble	1.35		
Baled	0.30	Others-compute as and when required per table of weights and specific gravities in AISC Manual of Steel Construction			

Notes to Appendix D

1. The factors assume 83% porosity for uncompacted paper and 50% for compacted paper. These figures are based on information obtained from Dr. Robert Schoenberger of Drexel Institute of Technology, the Lehigh waste Materials Company in Philadelphia, and experiments in weighing scrap paper. Some published data were available in the American Public Works Association (APWA) Municipal Refuse Disposal [1966], p. 47, and the American Institute of Steel Construction (AISC), Manual of Steel Construction [1964].
2. Data from Pacific Northwest Forest Products may be found in Oregon State Board of Health, Industrial Solid Waste Survey, Oregon: 1970.
3. Information from the AISC Manual, Dr. Schoenberger, and several rubber manufacturers was used. A porosity factor of 80% for uncompacted and 20% for compacted rubber refuse is assumed.
4. G. F. Kinney, Engineering Properties and Applications of Plastics, John Wiley and Sons, New York, 1957. Dr. Schoenberger supplied information on the porosity of plastic refuse.
5. These figures are based on data from Oregon [1969], APWA [1966], AISC [1964], and experiments in weighing glass bottles.
6. Data were available from Oregon [1970]. Additional information was obtained from Dr. Schoenberger and in discussions with local wiping rag companies.
7. Oregon [1970] and AISC [1964].
8. AISC [1964].
9. Data on metals in massive form was available in AISC [1964]. A porosity factor of 90% is assumed for scrap metals based on data in the Institute of Scrap Iron and Steel, Facts, 31st Edition Yearbook, 1970. Similar porosity factors are used for non-ferrous metals. Data on the weights of cans is based on estimates made by local scrap dealers and Dr. Schoenberger.

Appendix E

CALCULATION PROCEDURES

The method of calculating coefficients used here is based on techniques used to analyze conventional input-output data on inputs of factors of production per dollar output. (Isard, Langford, and Romanoff [1967]). The procedures allow the use of information for firms that could not give a detailed breakdown of the type of materials in their refuse but could tell the total quantity of waste generated.

Data for a hypothetical sector are presented on the following page. At the top of the table the information for each firm in the example is shown. The amount of each type of waste material for each firm is printed out. The next to last category (labeled "OTH", that is, other) is not specific and is included to account for materials that cannot be classified in the other twelve categories. The final category (labeled "COMP", that is, composite) represents the amount of waste that was reported but not identified as any particular type of material. All the data are in tons per year. Total amount of waste reported, employment and total waste per employee for each firm is also given for the hypothetical sector.

The remaining information summarizes the calculations for the sector. A preliminary coefficient for each type of material is first calculated. There was a total of 250 tons of paper

refuse reported by the firms in the sample. Note, however, that only two firms (Firms 1 and 4) reported paper specifically. Firms 2 and 3 although not indicating paper specifically, reported quantities of refuse not identified as any particular material. Some of this composite waste may be assumed to be paper since the other firms all reported paper refuse. To avoid underestimating the amount of paper waste generated in this sector, firms 2 and 3 are omitted in calculating the preliminary coefficient for paper refuse.

The 250 tons of the paper reported by firms 1 and 4 is divided by the sum of their employment; 600. Only the firms reporting paper specifically are included in the calculation. The coefficient that results, .417, is a weighted average of the paper generated per employee for the firms in the sample.

A similar calculation is made for each type of waste material. In calculating the preliminary coefficient for non-ferrous metals, firm 2 is included since it reported a specific amount of this material although it did not identify the remainder of its refuse. The result of these calculations appear in the column labeled "Preliminary Waste Per Employee." The last element in the column, 4.125, represents the total amount of waste generated per employee in this sector and is the sum of the coefficients for the various materials.

Table to Appendix E: Example of Method for Computing Coefficients

size	POP	WTD	TEX	PLAST	WLN	GLASS	ENGL	FE	NON FER	STEEL	CHEN	NTM	PM
1	50.00	0.0	300.00	0.0	0.0	0.0	0.0	0.0	100.00	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	200.00	0.0	1000.00	0.0	400.00	0.0	0.0	0.0	300.00	0.0	0.0	0.0	0.0
TOTAL													
1	450.00	100.	4.500										
2	800.00	200.	4.000										
3	200.00	50.	4.000										
4	1910.00	500.	3.800										
PHILA													
SAMPLE SUSA 68													
FIRMS													
EMPLOYMENT													
4.	10.	40											
850.	2000.	62											
Firm													
TOTALS													
PAPER	250.00	2.	600.	0.415667	0.398099	0.400	0.500	0.039810					
WDD	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
TEXTILE	1300.00	2.	600.	2.146666	2.070112	2.000	3.000	0.207011					
PLASTIC	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
RUBBER	400.00	2.	600.	0.666667	0.636958	0.800	0.800	0.063696					
GLASS	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
FOOD	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
FERROUS	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
NON-FER	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
STEEL	700.00	3.	800.	0.875000	0.836007	0.500	1.500	0.083601					
CHEN	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
SOIL/SAND/ASH	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
OTHER	0.0	2.	600.	0.0	0.0	0.0	0.0	0.0					
TOTAL													
3350.00	4.	950.	4.124998	3.941176	3.600	4.500	0.394118						

Reproduced from
best available copy.

OUTPUT PER EMPLOYEE (\$1000) 10.0000
ADJUSTED 0.955637
170 DEV ADJUSTED 0.222
STD DEV UNADJUSTED 0.291

If the total waste reported for all firms in the sector is summed (3350 tons) and divided by the total employment for the sample (850), a second estimate of total waste per employee is derived (3.941). This may differ from the total waste coefficient previously estimated because the method used to calculate the coefficients has omitted the firms that reported only composite figures. The ratio of the two estimates (shown at the bottom of the printout as "Adjustment" and equal to .955 in the example) is used to adjust each of the preliminary coefficients so that they add up to the actual total waste generated per employee reported in the sample. Final coefficients appear in the column labeled "Adjusted W/E?"

The printout also shows the maximum and minimum (nonzero) amount of each type of material generated per employee for the firms in the sample. Coefficients for tons of waste generated per dollar output are derived by dividing the mean waste per employee by an estimate of dollar output per employee for the sector. These coefficients are shown in the column labeled "W/\$" and represent the tons of waste per thousand dollars of output produced.

The standard deviation for the total waste coefficient is shown at the bottom of the printout. Since the coefficient is really a weighted mean, the standard deviation must be calculated

by weighting the squared deviation for each firm around the mean by the firm's employment,

$$(1) \text{ Weighted Standard Deviation} = \frac{\sum_i E_i (X_i - \bar{X})^2}{\sum_i E_i - 1}$$

where: E_i = employment of firm i ,

X_i = amount of waste generated per employee by firm i , and

$\bar{X}$ = average total waste per employee for the sector.

An unweighted standard deviation has also been calculated for each sector in order to help evaluate the sample. If there are significant differences in waste generation rates between large and small firms in the sector, the unweighted standard deviation will be much larger than the weighted.

$$(2) \text{ Unweighted Standard Deviation} = \frac{\sum (X_i - \bar{X})^2}{N - 1}$$

where: N = the number of firms in the sample.

Appendix F

SUMMARY OF PHILADELPHIA AND TEXAS
SOLID WASTE GENERATION COEFFICIENTS

Appendix F

SUMMARY OF PHILADELPHIA AND TEXAS SOLID WASTE GENERATION COEFFICIENTS

Philadelphia
SMSA Economy
1968

SIC	Philadelphia Waste Generation Sample				Texas Waste Generation Sample			
	Firms	Employ- ment	Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl. Total W/E Coef. (Tons)
20	599	48,522	209	29,537			95	15,941
2011	35	2,333	15	1,056	2.23	2.35	10	783
2013	45	2,601	13	1,806	11.81	5.67	3	128
2015	11	554	3	235	11.76	2.20	1	550
2021	1	66					2	297
2022	2	86	1	12	.99			0.2
2023	0	0						
2024	17	1,293	6	840	2.42	1.45	1	35
2026	42	4,141	19	1,553	.98	.49	4	228
2031	3	146	2	148	2.20	.30	2	183
2032	5	3,604					2	215
2033	31	2,125	11	1,069	5.17	4.95	1	1,550
2034	3	97	3	97	2.74	.39	2	1,020
2035	14	419	5	310	7.18	2.14		
2036	3	574	3	429	13.07	3.83	2	150
2037	11	1,668	2	468	4.25	0.05	1	375
2041	2	6					300	6.3
2042	16	441	3	125	2.91	1.62	2	141
2043	1	69	1	69	0.04	---	7	528
2044								3.1
2045	0	0						0.4
2046	0	0					1	200
2051	149	12,386	26	5,046	1.71	0.81	2	260
2052	7	2,111	3	2,491	4.00	2.26	1	3
2054	13	318	4	135	7.50	1.53	7	1,333
							1	700
								1.0
								0.1
								0.7
								0.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2
								1.5
								0.3
								1.3
								0.2
								0.1
								0.8
								2.1
								8.5
								0.3
								0.2

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample				Texas Waste Generation Sample				
SIC	Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
2062	2	1,718	14.39	1.15	1	525	1.8	---
2063								
2071	64	3,847	1.56	.86	3	407	0.4	0.1
2072	5	640	2.67	0.02				
2073	2	682	4.73	0.18				
2082	3	1,558	10.06	5.18	1	500	9.4	---
2083								
2084	3	171	0.16	0.10	1	2	1.0	---
2085	4	1,054	2.17	0.68				
2086	33	2,222	1.34	1.08	11	913	1.8	0.1
2087	13	332	1.92	2.35	2	240	3.2	1.0
2092								
2093								
2094	14	429	5.00	2.60	1	36	0.3	---
2095	7	147	0.10	0.	2	44	0.5	0.1
2096	2	213	1.21	---	3	3,150	1.3	1.3
2097	6	88	4.79	---	2	466	1.7	1.0
2098	5	209	0.46	0.34	5	70	0.2	0.1
2099	21	174	1.41	1.11	2	99	0.4	0.1
					7	510	0.7	0.3
21	10	1,569			0	0		
2111								
2121	9	1,483	3.36	---				
2131	1	86						
2141								

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample

Texas Waste Generation Sample

SIC	Firms	Employ- ment	Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
22	335	25,619	174	15,803	1.12	0.74	23	1,991	0.4	0.3
2211	12	461	5	124	1.23	0.71	2	657	0.7	---
2221	11	1,178	6	809	1.03	0.51	1	3	0.1	0.0
2231	15	1,058	7	297	1.03	0.77	2	559	1.0	---
2241	24	1,141	14	815	0.85	0.47	1	3		
2251	31	873	14	436	1.52	0.39				
2252	6	438	3	278	1.03	0.71				
2253	69	9,530	31	6,249	0.56	0.27				
2254	6	544	5	489	1.43	1.11				
2256	27	1,261	10	549	2.60	1.67				
2259	7	247	4	261	3.02	0.93	1	6	0.7	---
2261	12	650	6	370	4.07	0.56				
2262	4	435	3	254	2.92	1.87	1	17	3.5	---
2269	25	1,080	14	765	1.57	0.25				
2271	7	693	4	431	2.10	0.51	1	200	0.2	---
2272	4	961	3	941	0.48	0.22				
2279	5	540	4	148	1.84	1.31	2	57	0.7	0.2
2281	8	330	4	114	1.82	0.55				
2282	9	793	6	445	1.14	0.47				
2283	17	1,151	11	956	1.01	0.20				
2284	5	400	2	290	3.49	0.53	2	57	2.2	3.1
2291	4	84	4	259	0.50	0.08				
2292	5	419	2	137	3.02	0.36	2	46	6.8	0.5
2293	6	254	2	42	1.58	0.90	2	144	11.2	1.0
2294	6	248	3	38						

Appendix F - Cont.

Philadelphia SMSA Economy 1968				Philadelphia Waste Generation Sample				Texas Waste Generation Sample			
SIC	Firms	Employ- ment		Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
2295	1	59						1	6	2.5	---
2296											
2297	4	227		4	221	3.40	2.32	2	86	42.0	10.5
2298	3	555		2	69	3.79	0.24	1	30	0.1	---
2299	1	9		1	16	6.03	---	2	120	0.3	0.1
23											
2311	698	2,937		275	28,352			71	10,985		
2321	102	19,399		50	12,351	0.51	0.29	3	1,130	0.2	0.1
2322	13	814		4	294	0.71	0.21				
2323	4	781		4	781	0.22	0.05				
2327	11	267		5	118	1.71	0.87	1	65	0.1	---
2328	37	2,900		15	1,108	0.50	0.22	3	1,595	0.4	---
2329	11	572		6	331	0.17	0.04	2	1,051	0.1	0.1
2331	35	3,265		12	1,278	0.76	0.38	2	336	0.	0.
2335	19	1,188		7	447	1.42	0.75	2	302	0.2	0.
2337	107	6,438		37	2,811	1.15	0.52	10	1,712	0.2	0.1
2339	35	2,316		10	628	0.89	0.49	4	317	0.4	0.2
2341	29	2,272		12	604	0.64	0.46				
2342	16	1,145		5	592	1.21	0.23	5	1,300	0.3	0.
2351	7	391		1	19	1.21	0.	2	725	0.2	0.1
2352	6	137		3	86	0.96	0.18	2	68	0.3	0.1
2361	12	864		8	1,340	0.81	0.19	2	353	0.	0.
2363	32	2,888		13	1,552	1.79	1.00	4	358	0.3	0.1
2369	10	664		5	338	1.29	0.44	1	70	0.	---
2371	11	312		5	308	2.08	0.52				
	8	54		5	45	0.70	1.00				

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample

Texas Waste Generation Sample

SIC	Firms	Employ- ment	Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
2381	1	40	3	429	1.83	0.61	2	226	0.6	0.3
2384	3	429	1	50	1.22	---	1	225	0.1	---
2385	8	460	1	67	0.45	---	1	300	0.1	---
2386	1	67	2	225	2.36	0.	1	4	0.3	---
2387	3	139	8	212	1.14	0.84	2	31	0.2	0.2
2389	14	422	10	284	1.74	1.18	7	188	0.3	0.
2391	25	772	6	121	1.86	1.02	4	111	0.9	0.5
2392	34	659	8	230	1.23	0.60	2	115	0.5	0.1
2393	6	402	12	325	2.28	1.92	5	113	0.2	0.
2394	25	337	4	434	1.98	0.49	1	70	0.3	---
2395	22	367	2	147	0.55	0.09	1	60	1.7	---
2396	16	1,007	11	797	1.48	1.21	1	160	0.1	---
2397	2	147	53	1,086			56	3,514		
2399	32	1,022	5	29	270.30	53.96	17	522	419.7	83.3
24	162	2,301	15	268	13.50	9.17	1	100	24.0	---
2411	4	10	2	40			1	75	53.3	---
2421	21	85	2	11			16	853	14.2	6.9
2426	2	40	2	725			3	570	232.2	179.2
2429	1	11	2	34			3	108	24.7	17.8
2431	45	725	5	205	23.13	1.91	5	310	11.9	6.4
2432	2	34	13	436	13.89	2.97	1	210	31.4	---
2433	5	205	3	68			1	120	4.7	---
2441	13	436								
2442	1	12								
2443	3	68								

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

1968				Philadelphia Waste Generation Sample				Texas Waste Generation Sample			
SIC	Firms	Employ- ment	Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation	
2445	2	18	1	15	18.00	---	1	10	4.1	---	
2491	1	101	2	107	29.67	5.00	2	206	29.5	16.4	
2499	62	556	23	381	5.21	7.16	7	430	56.4	21.8	
25	232	7,572	81	4,801			40	3,305			
2511	44	556	10	376	10.94	5.74	8	756	4.2	1.4	
2512	47	779	14	363	3.49	3.18					
2514	24	1,537	6	617	8.14	1.76	1	200	0.7	---	
2515	19	475	10	383	2.18	1.67	8	631	0.3	0.1	
2517											
2521	5	608	2	462	1.59	0.10	2	46	2.0	0.	
2522	8	1,200	5	422	3.11	1.35	1	200	3.2	---	
2531	10	378	5	446	0.82	0.21	2	924	1.0	0.2	
2541	30	658	13	624	3.77	2.76	6	377	3.4	0.9	
2542	18	1,148	8	959	6.23	3.06	1	17	0.1	---	
2591	13	142	4	52	1.12	0.88	7	48	0.7	0.2	
2599	11	91	3	85	2.89	0.79	4	106	0.7	0.1	
26	245	22,764	95	12,209			29	5,939			
2611											
2621	11	3,836	5	1,429	10.13	3.96	2	2,700	11.7	0.3	
2631	13	2,515	10	2,025	9.69	2.44	2	335	14.6	1.3	
2641	22	1,429	6	1,057	3.66	4.24	1	800	2.5	---	
2642	10	839	5	407	2.64	0.91	3	420	4.0	0.8	
2643	14	1,327	5	729	10.04	8.54	2	270	2.5	0.2	
2644	1	18	1	18	1.39	---					
2645	18	522	9	436	3.90	3.03	2	60	2.5	0.9	

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample

Texas Waste Generation Sample

SIC	Employment		Total W/E		Standard Deviation	
	Firms	Employment	Firms	Employment	Coef. (Tons)	Standard Deviation
2646	1	84	4	197	16.54	4.46
2647	5	246	14	2,081	6.08	6.57
2649	40	2,707	12	1,197	14.17	8.00
2651	31	2,421	8	575	6.52	3.43
2652	21	1,567	9	1,488	13.36	7.91
2653	33	3,439	3	206	3.27	0.96
2654	7	489	4	364	5.57	2.68
2655	13	693				
2661	3	632				
27	999	38,156	249	20,718	2.99	1.15
2711	87	9,875	18	3,993	3.36	1.76
2721	20	7,146	5	4,525	2.21	0.84
2731	19	2,333	8	1,423	4.57	0.69
2732	8	402	3	304	2.00	1.06
2741	18	175	3	65	2.25	2.64
2751	375	4,700	60	2,708	2.50	2.03
2752	255	6,764	80	4,046	1.41	0.71
2753	18	529	6	387	2.97	0.88
2761	26	1,091	9	304	2.32	0.31
2771	11	232	4	104	2.34	1.68
2782	16	678	4	558	2.62	2.22
2789	38	1,382	17	659	2.20	1.28
2791	51	1,735	14	699	2.68	1.19
2793	25	1,063	15	751	0.71	0.19
2794	4	51	3	192		
2711	87	9,875	18	3,993	1.0	0.4
2721	20	7,146	5	4,525	0.1	0.1
2731	19	2,333	8	1,423	10.2	4.6
2732	8	402	3	304	0.3	0.1
2741	18	175	3	65	0.1	---
2751	375	4,700	60	2,708	1.5	0.4
2752	255	6,764	80	4,046	1.8	0.7
2753	18	529	6	387	0.2	0.1
2761	26	1,091	9	304	4.9	2.0
2771	11	232	4	104	1.2	---
2782	16	678	4	558	3.8	---
2789	38	1,382	17	659	3.0	---
2791	51	1,735	14	699	0.3	0.2
2793	25	1,063	15	751	1.9	0.4
2794	4	51	3	192	0.3	0.3

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Texas Waste Generation Sample

Philadelphia Waste Generation Sample

SIC	Employment		Employment		Total W/E		Standard Deviation		Total W/E		Standard Deviation	
	Firms	357	Firms	27,376	Coef. (Tons)	0.18	0.13	0.18	Firms	Empl. 19,030	Coef. (Tons)	0.13
2812	12	817	2	30	1.81	0.18	0.13	0.18	6	371	20.9	8.6
2813	7	2,592	4	587	63.06	15.79	0.13	15.79	2	52	1.0	1.0
2815	8	569	2	372	61.00	18.14	0.13	18.14	1	55	0.7	---
2816	14	1,258	8	516	3.27	3.76	0.13	3.76	8	11,531	43.4	6.3
2818	32	2,196	10	1,449	12.48	6.60	0.13	6.60	5	2,226	564.5	73.3
2819	26	6,767	14	6,655	4.68	2.14	0.13	2.14	4	1,644	7.9	2.3
2821									2	677	2.2	0.
2822												
2823												
2824	5	64	4	227	0.56	0.13	0.13	0.13	1	26	2.3	---
2831	1	3							1	40	0.2	---
2833	36	9,069	18	8,461	2.93	2.40	0.13	2.40	1	45	0.1	---
2834	20	947	5	493	4.39	1.69	0.13	1.69	3	291	0.7	0.2
2841	42	791	13	799	3.24	1.80	0.13	1.80	3	125	0.8	0.2
2842	13	458	8	287	4.62	5.32	0.13	5.32	6	223	2.9	0.4
2843	12	246	7	182	0.40	0.09	0.13	0.09	2	23	0.3	0.
2844	53	3,251	23	2,620	3.35	1.89	0.13	1.89	8	362	3.7	1.1
2851												
2861	6	536	2	149	7.89	1.94	0.13	1.94	4	810	1235.0	687.5
2871	2	15							2	22	5.8	5.9
2872	7	3,165	3	2,767	4.94	1.66	0.13	1.66	1	150	26.2	---
2879	12	345	4	262	10.82	4.79	0.13	4.79	2	11	39.9	34.6
2891	1	31	1	31	1.16	---	0.13	---				
2892	21	778	8	460	6.92	3.72	0.13	3.72	3	39	1.1	0.7
2893	1	3							1	124	1.6	---
2895	34	2,567	15	1,029	9.63	18.05	0.13	18.05	5	183	1.7	0.8
2899												

Appendix F - Cont.

Philadelphia SMSA Economy 1968				Philadelphia Waste Generation Sample				Texas Waste Generation Sample			
SIC	Employ- ment		Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation	
29	49	12,158	21	9,328	11.00	5.94	14	10,419	30.6	10.8	
2911	6	10,161	5	8,157	12.52	10.38	7	9,880	0.8	0.7	
2951	18	512	4	97	6.55	2.29	2	105	0.2	0.	
2952	7	450	5	447	1.11	0.51	3	427	1.3	0.3	
2992	18	1,035	7	622			2	7			
2999											
30	198	15,830	72	11,922	5.46	1.90	16	2,427			
3011	4	5,533	3	5,280							
3021	2	230									
3031	1	46	2	62	27.60	6.69					
3069	45	3,824	25	2,994	3.36	1.65	3	535	1.7	0.4	
3079	146	6,197	42	3,586	5.20	3.93	13	1,892	1.0	0.2	
31	52	2,265	25	1,445			16	2,733			
3111	7	593	3	276	3.35	0.48	1	65	3.8	---	
3121	1	136	1	33	0.76	---	1	16	0.8	---	
3131	1	22									
3141	8	469	2	307	2.38	1.13	2	925	0.2	0.	
3142	2	33	2	63	0.19	0.0	1	280	0.1	---	
3151							2	140	1.3	0.2	
3161	13	256	7	128	0.56	0.59	2	84	0.6	0.1	
3171	7	267	4	238	1.98	0.98	2	115	0.5	0.1	
3172	6	399	2	342	3.36	1.01	2	1,037	0.2	0.0	
3199	7	90	4	58	1.22	0.41	3	71	0.5	0.2	

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample

Texas Waste Generation Sample

SIC	Employment		Total W/E		Standard Deviation	Employment		Total W/E		Standard Deviation
	Firms	Employment	Firms	Employment		Firms	Employment	Firms	Employment	
32	274	14,069	84	8,364		60	6,435	2	40	0.5
3211	1	136	1	136	---	2	40	3	1,807	11.1
3221	2	302	2	405	1.06	3	1,807	2	51	1.8
3229	5	150	2	102	0.22	2	51	1	45	---
3231	37	1,417	11	678	1.73	1	45	1	125	---
3241	2	152	2	131	4.03	1	125	3	494	21.5
3251	5	180	1	71	---	3	494	1	178	---
3253	3	1,329	2	1,225	0.18	1	178	1	85	---
3255	8	522	4	451	3.51	1	85	2	555	0.1
3259	2	213	1	188	---	2	555	2	470	0.3
3261	1	4	1	4	---	2	470			
3262										
3263										
3264										
3269	8	212	2	117	2.02	1	90	2	34	0.1
3271	25	408	5	182	14.71	2	34	1	260	---
3272	41	1,140	8	165	11.18	11	550	9	325	156.1
3273	31	564	3	56	16.13	9	325			1.7
3274	1	102	1	79	88.61					
3275	4	511	2	296	167.33	2	292	3	67	5.9
3281	15	144	6	93	6.69	3	67	2	70	0.4
3291	20	1,554	5	601	2.13	2	70	2	560	0.
3292	8	772	5	525	12.60	2	560	2	31	15.0
3293	22	1,426	7	916	4.61	2	31	2	27	0.1
3295	16	681	4	92	2.62	2	27	2	215	0.5
3296	2	1,345	1	1,150	19.34	2	215	1	36	0.4
3297	7	703	5	645	4.07	1	36			---
3299	8	102	3	56	0.12	2	28			0.1

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

1968				Philadelphia Waste Generation Sample				Texas Waste Generation Sample				
SIC	Employment		Firms	Employment	Total W/E		Standard Deviation	Firms	Empl.	Total W/E		Standard Deviation
					Coef. (Tons)					Coef. (Tons)		
33	166	35,590	80	21,223	14.42	4.92	37	12,637	306.7	8.5		
3312	8	18,151	3	9,319	5.68	---	2	3,475	0.8	---		
3313	1	155	1	185	9.81	3.07	1	150	3.7	---		
3315	3	248	2	261	26.57	7.35	1	43	1.8	0.9		
3316	5	947	2	699	7.18	5.43	2	95	17.6	2.8		
3317	8	1,534	6	596	47.27	43.43	3	473	13.7	0.4		
3321	20	1,932	8	487	11.27	5.26	2	916	31.1	0.		
3322							2	1,011	2.3	2.1		
3323	10	1,051	3	259			2	575				
3331							2	1,840				
3332	1	5										
3333							1	500	0.1	---		
3334							1	1,700	58.4	---		
3339							1	150	4.0	---		
3341	4	764	4	969	12.09	13.74	1	374	43.7	8.5		
3351	17	789	8	671	27.31	19.61	3					
3352	1	442	2	430	4.95	1.56	1	350	1.6	---		
3356	1	344	4	1,463	1.64	0.64						
3357	6	1,527	1	498	2.79	---	1	350	0.3	---		
3361	4	731	8	1,132	0.93	0.57	2	47	1.3	0.		
3362	18	1,444	11	556	4.26	1.82	2	45	3.9	1.6		
3369	23	854	4	289	17.57	15.10	4	218	2.9	1.4		
3391	10	500	5	2,330	14.44	7.41	1	120	2.0	---		
3392	9	3,142	1	98	3.09	---	2	183	4.2	0.1		
3399	1	181	6	778	10.72	11.09	1	22	0.5	---		
3399	16	849										

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample				Texas Waste Generation Sample					
1968		Total W/E		Standard Deviation		Total W/E		Standard Deviation	
Firms	Employ- ment	Firms	Employ- ment	Coef. (Tons)	Standard Deviation	Firms	Empl.	Coef. (Tons)	Standard Deviation
891	37,887	288	22,774	3.16	2.53	80	13,272	9.0	1.1
3411	3,114	5	2,161	2.56	---	3	853		
3421	18	1	18	3.55	1.37				
3423	1,278	12	1,139			1	75	1.1	---
3425	4					2	31	0.3	0.1
3429	1,236	11	731	2.36	2.34	1	44	9.0	---
3431	361	2	529	16.46	0.85	1	250	0.1	---
3432	153	3	445	4.93	0.53	1	550	16.5	---
3433	1,139	7	392	2.07	1.07	5	1,240	5.7	6.0
3441	3,738	17	2,328	3.93	2.01	14	1,631	2.2	0.5
3442	1,595	17	1,085	2.07	1.02	5	1,089	1.4	0.1
3443	2,471	14	975	3.78	2.22	6	1,738	4.6	0.9
3444	3,204	42	1,677	2.77	2.57	8	394	1.1	0.7
3446	956	25	459	1.65	1.24	1	1	0.0	---
3449	221	2	76	0.49	0.21	2	54	0.3	0.
3451	837	20	327	2.61	1.84	2	88	1.8	0.4
3452	4,452	10	4,183	2.96	0.71	2	285	2.8	1.8
3461	3,533	17	1,056	5.15	3.66	3	1,720	0.2	0.2
3471	1,194	19	569	1.90	1.24	3	97	0.4	0.1
3479	931	11	457	2.31	2.09	3	128	1.2	0.3
3481	1,442	12	500	3.40	3.00	2	58	11.3	3.8
3491	866	3	296	4.43	1.73	2	311	8.1	0.4
3492									
3493	599	5	163	2.21	0.86	2	36	0.2	0.
3494	3,002	11	2,178	3.59	1.26	5	1,915	3.1	0.9
3496	350	1	361	0.35	---				

Philadelphia
SMSA Economy
1968

1968			Philadelphia Waste Generation Sample			Texas Waste Generation Sample			
SIC	Firms	Employ- ment	Total		Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
			W/E Coef. (Tons)	W/E Coef. (Tons)					
3497	2	308	1	122	---	2	572	1.2	0.6
3498	14	286	7	184	1.10	4	192	2.0	0.7
3499	36	599	13	363	2.52				
35	939	56,369	329	38,051		113	17,708		
3511	2	9,702	2	8,091	1.66				
3519	5	76	1	22	---				
3522	7	100	4	186	0.32	3	470	0.8	0.1
3531	6	257	3	212	0.80	3	555	0.9	0.6
3532	1	1	1	4	---	1	210	2.8	---
3533	2	32				7	3,080	4.0	1.1
3534	6	145	5	48	0.89	1	150	0.3	---
3535	10	914	3	865	0.11	1	43	1.2	---
3536	9	413	3	193	2.51	1	165	5.8	---
3537	9	3,677	6	2,327	0.61				
3541	18	419	9	264	4.56	4	88	1.1	0.3
3542	11	654	6	463	0.78				
3544	210	3,130	56	1,307	1.94	6	140	1.6	0.5
3545	5	169				2	158	11.8	1.1
3548	7	101	3	107	2.55	1	80	2.7	---
3551	19	617	8	480	0.87				
3552	29	2,541	20	2,745	1.65				
3553	3	60	1	50	---				
3554	26	2,359	12	1,172	1.08	2	45	0.6	0.1
3555	22	1,177	6	609	1.80	1	9	0.6	---
3559	42	2,875	16	2,213	2.38	2	255	0.2	0.
3561	14	1,106	8	957	1.11	5	441	0.8	0.3
						7	689	1.5	0.2

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample

Texas Waste Generation Sample

SIC	Firms	Employ- ment	Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
3562	8	3,796	5	3,368	2.86	0.79	2	91	2.3	0.8
3564	7	768	1	6	0.17	---	2	114	2.0	0.7
3565	27	157	7	112	4.51	2.30	1	3	0.3	---
3566	16	2,532	7	1,475	3.91	1.74	2	460	32.9	15.4
3567	14	1,394	11	1,091	2.11	0.99	2	127	0.2	0.
3569	20	2,807	9	2,191	0.94	0.56	2	66	3.2	3.2
3572										
3573	20	9,792	7	3,445	0.80	0.27	2	1,118	0.2	0.
3574										
3576	3	52	2	31	0.44	0.56	1	7	0.6	---
3579	4	156	3	295	0.68	0.20				
3581	5	130	4	152	1.36	0.39	1	120	0.1	0.1
3582	1	5	1	5	0.80	---	1	4	0.5	0.
3585	24	2,571	12	2,024	3.079	1.62	6	870	3.7	3.3
3586	5	400	3	448	1.46	0.83	2	125	0.8	0.3
3589	15	382	4	54	3.63	2.45	2	55	0.4	0.3
3599	81	902	80	1,039	2.78	3.28	40	1,125	1.2	0.3
36	375	59,251	135	25,448			44	4,480		
3611	41	1,960	16	1,236	1.99	1.37	1	45	0.2	---
3612	7	605	5	354	0.97	0.60	3	147	0.2	0.1
3613	24	11,087	8	7,636	1.42	0.15	1	170	1.4	---
3621	11	1,130	6	812	2.45	1.84	1	15	1.3	---
3622	11	1,241	4	829	1.30	0.45	3	430	0.1	0.
3623	5	233	3	813	3.68	0.58				
3624	4	33	2	23	3.39	0.21	2	93	0.2	0.3
3629	10	1,684	2	133	1.67	0.02	1	750	0.2	---

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

1968				Philadelphia Waste Generation Sample				Texas Waste Generation Sample				
SIC	Firms	Employ- ment	Total		Firms	Employ- ment	Total		Firms	Empl.	Total	
			W/E Coef. (Tons)	Standard Deviation			W/E Coef. (Tons)	Standard Deviation			W/E Coef. (Tons)	Standard Deviation
3631	1	13	1	13	3.31	---	---	2	35	0.5	0.1	
3632								1	25	1.4	---	
3633	2	28	1	7	4.86	---	---					
3634	3	45	1	22	1.59	---	---	2	360	1.3	0.	
3635												
3636												
3639	3	329	2	24	0.79	0.17	0.17	1	6	0.8	---	
3641	1	145	1	145	3.13	---	---	2	292	29.2	1.4	
3642	66	3,976	26	1,598	1.43	1.40	1.40	2	305	0.	0.	
3643	23	1,706	8	738	1.25	0.85	0.85	3	243	1.4	0.2	
3644	11	490	6	298	3.26	0.89	0.89					
3651	9	5,179	2	3,309	1.77	0.35	0.35	3	144	7.2	0.6	
3652	11	1,039	2	71	0.68	0.13	0.13	1	50	0.8	---	
3661	4	167	3	187	1.21	0.21	0.21	3	79	0.8	0.	
3662	35	19,352	6	1,985	1.53	0.89	0.89	1	320	0.	---	
3671								1	80	0.2	---	
3672	4	93	2	66	1.03	0.09	0.09	1	3	2.3	---	
3673	1	10	1	6	0.87	---	---					
3674	8	1,037	2	219	1.98	0.32	0.32	2	61	1.0	0.1	
3679	63	6,280	19	3,483	1.70	0.89	0.89	3	347	0.5	0.3	
3691	4	1,305	3	1,258	2.49	0.30	0.30	1	260	1.3	---	
3692												
3693	3	44						1	40	0.7	---	
3694	6	174	1	60	5.59	---	---	1	120	1.2	---	
3699	3	9	2	123	0.66	0.36	0.36	1	60	0.5	---	

Appendix F - Cont.

Philadelphia SMSA Economy 1968				Philadelphia Waste Generation Sample ^{1/2}				Texas Waste Generation Sample			
SIC	Firms	Employ- ment		Firms	Employ- ment	Total W/E Coef. (Tons)	Standard Deviation	Firms	Empl.	Total W/E Coef. (Tons)	Standard Deviation
37	100	42,148		37	23,923			33	22,343		
3711	2	782		2	5,740	3.09	0.60	2	4,506	1.2	0.
3712											
3713	13	343		5	94	2.75	1.17	3	202	1.2	0.2
3714	27	8,658		8	1,877	7.69	2.26	7	655	5.3	3.0
3715	10	3,277		5	2,963	2.09	1.48	1	700	1.7	---
3721								1	13,000	0.9	---
3722	3	12,782		2	2,244	12.68	1.25	2	353	0.5	0.0
3723	3	2,117						2	10	2.6	0.8
3729	24	7,814		9	6,958	2.74	0.40	1	30	0.7	---
3731	4	4,885		3	3,638	4.79	0.40	3	1,735	10.8	1.8
3732	6	298		1	354	6.92	---	2	77	0.8	0.1
3741								1	29	6.2	---
3742=	1	940						1	81	0.7	---
3751											
3791	2	29		1	22	0.94	---	4	872	3.9	1.2
3799	5	223		1	33	0.97	---	3	93	1.1	0.9
38	166	17,622		62	11,534			18	2,616		
3811	26	1,811		11	1,266	0.87	0.64	2	287	0.1	0.1
3821	40	12,552		16	8,311	1.19	0.40	1	40	0.2	---
3822	10	482		6	449	1.15	0.55				
3831	10	107		2	94	3.88	0.25	3	378	0.6	0.
3841	15	662		6	366	1.87	0.49	1	4	0.5	---
3842	31	903		11	463	2.86	0.98	4	225	0.2	0.1
3843	18	895		7	523	0.33	0.30	1	136	0.	---

Appendix F - Cont.

Philadelphia
SMSA Economy
1968

Philadelphia Waste Generation Sample

Texas Waste Generation Sample

SIC	Employment		Total		Standard		Employment		Total		Standard	
	Firms	ment	Firms	ment	Deviation	Deviation	Firms	ment	Firms	ment	Deviation	Deviation
3851	3	2					3	62	0.42	0.28		
3861	13	208										
3871												
3872												
39												
3911	285	8,397	119	4,742			36	1,808				
3912	28	137	10	104		0.42	2	315		0.3	0.1	
3913	4	64	1	40		---						
3914	5	3										
3914	7	117	4	51		3.76	2	18		1.1	0.2	
3931	4	90					2	165		0.6	0.	
3941	16	1,154	8	539		2.61	1	65		2.5	---	
3942	4	34	2	21		0.02						
3943	1	169										
3949	19	652	10	366		0.96	3	141		0.5	0.0	
3951	2	151	1	3		---						
3952	3	498										
3953	21	357	9	243		0.31	4	79		0.3	0.2	
3955	5	184	3	31		0.69	1	45		8.7	---	
3961	7	153	4	102		0.08						
3962	8	195	3	54		0.47	2	43		0.4	0.1	
3963	3	118	2	99		0.32	2	14		0.3	0.	
3964	2	38	1	11		---	2	43		0.2	0.1	
3991	14	249	6	85		6.44	2	15		3.0	0.4	
3993	67	1,290	27	647		2.08	6	457		1.5	0.2	
3994	13	236	8	215		0.33	1	65		0.2	---	
3996	2	768	1	641		---	2	63		2.3	0.1	
3999	50	1,740	19	1,490		3.11	4	280		1.4	0.8	
TOTAL	7,132	537,403	2,540	319,931			944	164,347				

Appendix G

BEST CHOICE COEFFICIENTS

SOLID WASTE GENERATION COEFFICIENTS, MANUFACTURING INDUSTRIES (TONS/EMP/YEAR)*

157

STC NO	PAPER	WOOD	TEXTILE	PLSTIC	PUMBER	GLASS	FOOD	FERROUS	NONFER	PETROL/ PAINTS	CHEM	SAND/ ASHES	OTHER	SLUDGE	TOTAL	SOURCE
2121	1.680	1.680	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.360	K
2131	0.137	0.052	0.0	0.018	0.0	0.0	0.036	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.231	K
2141	0.182	0.795	0.032	0.014	0.001	0.0	0.015	0.015	0.0	0.0	0.014	0.048	0.0	0.009	1.226	K
2211	0.776	0.0	0.346	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.122	
2221	0.419	0.0	0.145	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.266	0.0	0.0	1.270	
2231	0.624	0.062	0.289	0.0	0.0	0.057	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.332	
2241	0.691	0.0	0.312	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.036	0.0	1.025	
2251	0.515	0.0	0.121	0.0	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.120	0.0	0.0	0.651	
2252	0.954	0.0	0.563	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.517	
2253	0.526	0.0	0.339	0.011	0.0	0.0	0.0	0.114	0.0	0.008	0.029	0.0	0.0	0.0	1.031	
2254	0.173	0.015	0.614	0.030	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.0	0.0	0.0	0.442	
2256	0.661	0.114	0.330	0.139	0.060	0.072	0.0	0.0	0.0	0.0	0.0	0.0	0.383	0.0	1.425	
2259	1.200	0.0	1.360	0.0	0.0	0.0	0.0	0.062	0.0	0.0	0.0	0.0	0.0	0.0	2.602	
2261	0.970	0.0	0.561	0.0	0.0	0.0	0.0	0.035	0.0	0.0	0.0	0.0	0.043	0.0	3.016	
2262	3.543	0.0	0.326	0.0	0.204	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.073	
2269	1.872	0.128	0.770	0.0	0.0	0.0	0.0	0.016	0.0	0.0	0.136	0.0	0.0	0.0	2.922	
2271	0.675	0.0	0.903	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.575	
2272	1.008	0.0	1.091	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.099	
2279	0.150	0.0	0.200	0.103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.475	
2281	0.281	0.0	0.193	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	1.358	0.0	1.549	
2282	1.528	0.0	0.292	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.820	
2293	0.533	0.0	0.352	0.0	0.0	0.0	0.0	0.052	0.0	0.0	0.0	0.0	0.0	0.0	1.117	
2294	0.900	0.0	0.108	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.108	
2291	0.407	0.019	1.427	0.0	0.006	0.0	0.0	0.074	0.0	0.0	0.0	0.0	0.0	0.449	3.242	
2292	0.482	0.0	0.019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.501	
2293	0.192	0.0	2.254	0.0	0.0	0.0	0.0	0.577	0.0	0.0	0.0	0.0	0.0	0.0	3.223	
2294	0.143	0.0	1.111	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.0	0.0	11.287	
2295	0.299	0.119	4.780	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.777	0.0	2.500	0.0	4.475	
2296	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2297	0.279	0.020	0.0	0.0	0.0	0.0	0.0	0.112	0.037	0.0	0.0	1.233	0.0	0.0	2.551	
2298	2.541	0.0	0.845	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.786	
2299	0.195	0.0	5.837	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.032	
2311	0.240	0.0	0.252	0.047	0.0	0.0	0.0	0.013	0.0	0.0	0.0	0.011	0.0	0.0	0.560	
2321	0.191	0.048	0.521	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.760	
2322	0.034	0.037	0.173	0.0	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.0	0.0	0.0	3.228	
2323	1.159	0.0	0.548	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.707	
2327	0.173	0.0	0.231	0.0	0.0	0.034	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.488	
2329	0.072	0.0	0.072	0.0	0.0	0.0	0.0	0.012	0.0	0.0	0.0	0.010	0.0	0.0	0.166	
2329	0.390	0.0	0.366	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.786	
2331	0.370	0.0	0.956	0.034	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.470	
2335	0.353	0.005	0.618	0.075	0.0	0.0	0.0	0.011	0.0	0.0	0.090	0.0	0.0	0.0	1.152	
2337	0.114	0.0	0.763	0.0	0.0	0.0	0.0	0.008	0.0	0.0	0.0	0.0	0.0	0.0	0.385	
2339	0.090	0.0	0.555	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.645	

SIC NO	PAPER	WOOD	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FERRUS	NUMBER	PAINTS	CHEM	SAND/ ASHES	OTHER	SLUDGE	TOTAL	SOURCE
2542	0.022	0.284	3.356	0.0	0.0	0.013	0.0	3.351	0.0	1.668	0.0	0.0	0.0	0.0	6.629	
2591	0.747	0.096	3.113	0.0	0.0	0.0	0.0	0.103	0.0	0.0	0.0	0.0	0.0	0.0	1.121	
2594	1.397	0.244	0.233	0.0	0.0	0.0	0.0	1.049	0.0	0.0	0.0	0.0	0.0	0.0	2.650	
2611	0.0	5.400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.100	31.500	R
2621	5.352	0.426	3.043	0.0	0.0	0.0	0.0	0.036	0.0	0.0	0.0	0.0	0.0	4.104	13.170	
2631	1.730	2.363	1.272	0.0	0.0	0.188	0.0	3.779	0.0	0.0	0.0	1.363	0.0	1.316	4.612	
2641	2.258	0.103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.656	
2642	2.340	0.233	0.074	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.646	
2643	0.480	0.023	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.0	0.0	13.330	
2644	1.389	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.414	
2645	3.778	0.174	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.414	
2646	0.0	5.200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.200	
2647	1.423	1.926	0.0	0.0	0.0	0.0	0.0	0.062	0.0	0.0	0.0	0.0	0.0	0.0	15.563	
2649	5.550	0.432	0.0	0.0	0.0	0.0	0.0	0.071	0.0	0.0	0.0	0.0	0.0	0.0	6.313	
2651	1.661	0.122	0.021	0.0	0.0	0.042	0.037	0.024	0.0	0.0	0.0	0.177	0.0	0.0	14.164	
2652	4.893	0.184	0.0	0.0	0.0	0.0	0.0	0.090	0.0	0.0	0.0	0.0	0.0	0.0	5.517	
2653	12.504	0.021	0.019	0.0	0.0	0.0	0.0	0.037	0.0	0.0	0.0	0.0	0.0	0.0	11.464	
2654	2.419	0.571	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.271	
2655	2.470	0.333	0.0	0.0	0.0	0.0	0.0	3.090	0.0	0.0	0.0	0.0	0.0	0.0	5.563	
2661	30.900	0.333	0.0	0.0	0.0	0.0	0.0	10.300	0.0	0.0	60.300	0.0	0.0	0.0	137.500	T
2711	2.881	0.013	0.0	0.0	0.0	0.024	0.0	0.011	0.010	0.0	0.0	0.0	0.0	0.0	2.841	
2721	3.135	0.016	0.031	0.0	0.0	0.005	0.028	0.130	0.069	0.0	0.0	0.0	0.0	0.0	3.356	
2731	2.153	0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.019	0.0	0.0	0.0	0.0	0.0	2.211	
2732	3.737	0.473	3.186	0.0	0.0	0.112	0.0	0.0	0.066	0.0	0.0	0.0	0.0	0.0	4.371	
2741	1.731	0.0	0.0	0.0	0.0	0.0	0.0	0.169	0.0	0.0	0.0	0.0	0.0	0.0	2.200	
2751	1.597	0.052	0.0	0.0	0.0	0.0	0.0	0.066	0.065	0.0	0.0	0.051	0.0	0.0	2.446	
2752	2.309	0.055	0.028	0.033	0.0	0.001	0.0	0.016	0.052	0.003	0.0	0.0	0.0	0.0	2.457	
2753	1.153	0.103	0.066	0.0	0.0	0.0	0.0	0.023	0.035	0.027	0.0	0.0	0.0	0.0	1.407	
2761	2.853	0.009	0.0	0.0	0.0	0.0	0.0	0.009	0.101	0.0	0.0	0.0	0.0	0.0	2.472	
2771	1.622	0.203	0.293	0.030	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.115	
2782	1.878	0.043	0.0	0.0	0.0	0.035	0.0	0.141	0.233	0.0	0.0	0.0	0.0	0.0	2.136	
2789	2.377	0.014	0.0	0.0	0.0	0.065	0.0	0.120	0.0	0.0	0.0	0.001	0.0	0.0	2.621	
2791	1.663	0.223	0.031	0.0	0.0	0.0	0.0	0.023	0.264	0.0	0.0	0.0	0.002	0.0	2.146	
2793	1.917	0.383	0.170	0.334	0.0	0.022	0.0	0.125	0.024	0.0	0.0	0.0	0.0	0.0	2.675	
2794	0.530	0.077	0.0	0.077	0.0	0.0	0.0	0.027	0.0	0.0	0.0	0.0	0.0	0.0	0.711	
2813	1.284	0.025	0.009	0.001	0.003	2.093	0.0	0.194	0.004	0.001	10.352	6.399	0.0	0.0	23.345	T
2815	0.094	0.013	0.007	0.0	0.0	0.011	0.0	0.0	0.0	27.634	30.101	3.0	5.437	0.0	63.064	
2816	2.314	0.302	0.0	0.0	0.402	0.0	0.0	1.066	0.0	0.923	0.0	54.723	1.207	0.0	60.597	
2818	2.548	0.253	0.397	0.113	0.0	0.0	0.0	0.818	0.204	0.104	30.289	7.734	0.0	0.919	43.448	T
2819	1.047	0.296	0.087	0.105	0.025	0.397	0.0	0.674	0.091	0.063	8.583	0.316	0.0	0.0	11.707	

Reproduced from
best available copy.

SIC NO	PAPER	WOOD	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FERRICUS	MONPER	PAINTS	PETROL/	SAND/	OTHER	SLUDGE	TOTAL	SOURCE
3221	0.911	0.200	0.329	0.018	0.125	1.498	0.0	0.128	0.097	0.0	0.0	0.175	0.533	0.0	3.714	
3229	1.284	0.0	0.0	0.0	0.0	0.553	0.0	0.287	0.0	0.0	0.0	0.0	0.0	0.0	4.220	
3231	0.671	0.163	0.0	0.037	0.0	0.246	0.0	1.506	0.0	0.0	0.0	0.0	0.0	0.0	4.680	
3241	1.079	0.016	0.0	0.0	0.0	0.0	0.0	0.300	0.0	0.021	0.0	0.0	0.0	0.0	9.785	
3251	0.070	0.004	0.0	0.0	0.0	0.0	0.0	0.037	0.0	0.0	0.0	0.0	0.0	0.0	30.165	
3252	0.769	0.093	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.760	
3255	1.160	0.633	0.0	0.016	0.0	0.0	0.0	0.049	0.0	0.0	0.0	0.0	0.0	0.0	6.760	
3259	0.005	0.025	0.0	0.064	0.0	0.0	0.0	0.064	0.038	0.0	0.0	0.0	0.0	0.0	13.523	
3261	0.549	0.0	0.0	0.0	0.0	1.064	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.104	
3264	0.100	0.0	0.0	0.0	0.0	0.350	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.440	
3269	0.682	0.341	0.0	0.0	0.0	0.0	0.0	0.361	0.0	0.0	0.0	0.0	0.0	0.0	2.017	
3271	0.199	0.284	0.0	0.0	0.0	0.0	0.0	0.259	0.0	0.0	0.0	0.0	0.0	0.0	16.703	
3272	1.007	0.038	0.0	0.0	0.0	0.0	0.0	2.006	0.0	0.0	0.0	0.0	0.0	0.0	11.179	
3273	0.054	0.0	0.0	0.0	0.0	0.0	0.0	0.330	0.0	0.0	0.0	0.0	0.0	0.0	16.004	
3274	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.706	
3275	1.430	1.891	0.0	0.0	0.0	0.0	0.0	0.0	0.645	0.0	0.0	0.0	0.0	0.0	6.884	
3276	0.094	0.563	0.0	0.0	0.322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.133	
3281	0.655	0.522	0.0	0.0	0.0	0.0	0.0	3.415	0.0	0.0	0.0	0.0	0.0	0.0	12.661	
3282	0.623	0.343	0.739	0.0	0.0	0.0	0.0	0.024	0.0	0.0	0.0	0.0	0.0	0.0	4.611	
3293	0.122	0.001	0.0	0.034	0.0	0.0	0.0	0.278	0.115	0.0	0.0	0.0	0.0	0.0	2.625	
3295	0.161	0.0	0.0	0.0	0.0	0.0	0.0	3.477	0.0	0.0	0.0	0.0	0.0	0.0	20.155	
3296	7.599	1.197	0.065	0.587	0.222	0.0	0.130	0.594	0.098	1.333	0.0	0.0	0.0	0.0	4.071	
3297	0.630	0.244	0.0	0.0	0.0	0.0	0.0	0.239	0.0	0.0	0.0	0.0	0.0	0.0	0.116	
3299	0.085	0.0	0.0	0.0	0.0	0.0	0.0	0.239	0.0	0.0	0.0	0.0	0.0	0.0	0.116	
3311	0.246	0.0	0.0	0.0	0.025	0.0	0.0	1.232	0.0	0.0	0.0	0.0	0.0	0.0	2.442	
3312	0.071	0.035	0.013	0.0	0.013	0.013	0.0	1.690	0.013	0.0	0.0	0.0	0.0	0.0	7.866	
3313	0.396	0.422	0.0	0.0	0.0	0.0	0.0	4.865	0.0	0.0	0.0	0.0	0.0	0.0	16.414	
3315	0.435	0.125	0.0	0.0	0.0	0.0	0.0	0.476	0.0	0.0	0.0	0.0	0.0	0.0	5.883	
3316	0.821	0.355	0.0	0.0	0.0	0.0	0.0	25.406	0.0	0.0	0.0	0.0	0.0	0.0	4.815	
3317	0.333	0.083	0.0	0.0	0.0	0.0	0.0	10.227	0.823	0.0	0.0	0.0	0.0	0.0	20.360	
3321	0.033	0.121	0.0	0.0	0.0	0.0	0.0	0.697	0.0	0.0	0.0	0.0	0.0	0.0	4.952	
3322	0.135	0.317	0.0	0.0	0.0	0.0	0.0	0.030	0.0	0.0	0.0	0.0	0.0	0.0	11.271	
3323	0.716	0.134	0.0	0.0	0.0	0.0	0.0	0.019	0.0	0.0	0.0	0.0	0.0	0.0	2.364	
3331	0.267	0.336	0.0	0.0	0.0	0.0	0.0	0.021	1.868	0.0	0.0	0.0	0.0	0.0	0.0	
3332	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3333	0.144	0.102	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3334	0.059	0.037	0.059	0.018	0.0	0.0	0.0	1.177	0.034	0.0	0.0	0.0	0.0	0.0	0.0	
3339	0.432	0.091	0.0	0.041	0.0	0.0	0.0	0.0	0.197	0.0	0.0	0.0	0.0	0.0	12.084	
3341	0.210	0.0	0.0	0.045	0.0	0.0	0.0	0.0	26.577	0.0	0.0	0.0	0.0	0.0	31.315	
3352	0.028	0.047	0.0	0.0	0.0	0.070	0.0	0.067	3.967	0.0	0.0	0.0	0.0	0.0	7.243	
3356	0.456	0.374	0.0	0.0	0.0	0.080	0.0	0.072	0.550	0.103	0.0	0.0	0.0	0.0	1.637	
3357	1.004	0.033	0.0	0.120	0.0	0.0	0.0	0.0	1.606	0.0	0.0	0.0	0.0	0.0	2.820	
3361	0.096	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.434	
3362	0.042	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3369	0.152	0.013	0.022	0.010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3391	0.508	0.037	0.0	0.0	0.0	0.0	0.0	4.167	0.0	0.0	0.0	0.0	0.0	0.0	5.729	

SIC NO	PAPER	WOOD	TEXTILE	PLASTIC	MURDER	GLASS	FOOD	PERFUMES	HOMER	PETROLEUM	PAINTS	CHEM	ASHES	OTHER	SLOUGHS	TOTAL	SPRINT
3548	0.453	0.371	0.0	0.0	0.0	0.0	0.0	4.202	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.026	
3551	0.849	0.443	0.0	0.0	0.0	0.0	0.0	0.404	0.179	0.0	0.0	0.0	0.0	0.0	0.0	1.175	
3552	1.012	0.384	0.037	0.010	0.013	0.015	0.0	1.561	0.070	0.035	0.0	0.045	0.0	0.0	0.0	1.170	
3553	1.420	0.883	0.0	0.0	0.0	0.0	0.0	2.403	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.720	
3554	0.227	0.074	0.064	0.0	0.0	0.0	0.0	0.566	0.239	0.0	0.0	0.0	0.0	0.0	0.0	4.167	
3555	0.886	0.306	0.229	0.275	0.382	0.458	0.0	0.593	0.472	0.0	0.0	0.0	0.0	0.0	0.0	4.620	
3559	0.341	0.523	0.0	0.0	0.0	0.0	0.072	1.188	0.013	0.0	0.0	0.0	0.0	0.0	0.0	4.162	
3561	0.475	0.138	0.0	0.0	0.0	0.0	0.0	0.646	0.212	0.007	0.0	0.0	0.0	0.0	0.0	1.954	
3562	0.727	0.353	0.372	0.029	0.029	0.054	0.0	0.827	0.008	0.041	0.0	0.0	0.0	0.0	0.0	2.478	
3565	0.333	0.056	0.0	0.0	0.0	0.0	0.0	1.211	0.444	0.0	0.0	0.089	0.067	0.0	0.0	4.200	
3565	0.209	1.112	0.0	0.0	0.0	0.0	0.0	0.0	0.375	0.0	0.0	0.0	0.0	0.0	0.0	1.206	
3566	2.147	0.162	0.010	0.033	0.035	0.018	0.0	1.100	0.159	0.058	0.0	0.081	0.141	0.028	0.0	1.312	
3567	1.050	0.198	0.071	0.033	0.074	0.089	0.0	0.325	0.313	0.125	0.0	0.0	0.345	0.062	0.0	2.165	
3569	0.334	0.187	0.0	0.037	0.001	0.001	0.0	3.323	0.074	0.0	0.0	0.0	0.0	0.0	0.0	3.335	
3572	0.958	0.200	0.0	0.0	0.0	0.0	0.0	1.023	0.364	0.0	0.0	0.0	0.0	0.0	0.0	1.565	
3573	0.662	0.016	0.035	0.009	0.017	0.033	0.026	0.017	0.012	0.0	0.0	0.001	0.0	0.0	0.0	0.794	
3576	0.125	0.0	0.0	0.0	0.0	0.0	0.0	0.311	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.432	
3579	0.453	0.135	0.0	0.0	0.0	0.0	0.0	3.020	0.077	0.0	0.0	0.0	0.0	0.0	0.0	3.684	
3581	0.643	0.0	0.0	0.031	0.0	0.0	0.0	0.718	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.562	
3582	0.200	0.201	0.0	0.0	0.0	0.0	0.0	3.400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.410	
3585	1.851	0.540	0.017	0.020	0.004	0.0	0.0	0.224	0.0	0.127	0.0	0.0	0.0	0.0	0.0	3.333	
3586	0.092	0.183	0.0	0.036	0.0	0.0	0.0	1.032	0.0	0.051	0.0	0.0	0.0	0.0	0.0	1.904	
3589	2.269	0.401	0.0	0.0	0.0	0.0	0.0	0.964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.035	
3599	0.760	0.131	0.0	0.0	0.0	0.0	0.0	1.719	0.170	0.001	0.004	0.0	0.0	0.0	0.0	2.765	
3611	0.743	0.491	0.0	0.040	0.0	0.222	0.0	0.434	0.057	0.0	0.0	0.002	0.0	0.0	0.0	1.763	
3612	0.229	0.022	0.0	0.041	0.0	0.0	0.0	0.094	0.168	0.084	0.0	0.352	0.0	0.0	0.0	0.370	
3613	0.360	0.045	0.025	0.065	0.0	0.0	0.0	0.732	0.085	0.054	0.0	0.073	0.0	0.0	0.0	1.421	
3621	1.059	0.145	0.023	0.0	0.0	0.0	0.0	0.690	0.207	0.334	0.0	0.0	0.0	0.0	0.0	2.648	
3622	0.316	0.597	0.0	0.0	0.0	0.047	0.0	0.290	0.0	0.0	0.0	0.050	0.0	0.0	0.0	1.330	
3623	0.659	0.497	0.039	0.0	0.0	0.0	0.0	1.179	0.171	0.0	0.0	1.134	0.0	0.0	0.0	1.674	
3624	0.261	0.522	0.0	0.209	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.400	0.0	0.0	0.0	3.342	
3629	0.724	0.093	0.0	0.0	0.0	0.0	0.0	0.900	0.106	0.0	0.0	0.0	0.0	0.0	0.0	1.462	
3631	1.376	0.437	0.0	0.0	0.0	0.0	0.0	2.156	0.0	0.0	0.0	0.055	0.0	0.0	0.0	3.069	
3632	1.129	0.0	0.0	0.0	0.0	0.0	0.0	0.043	0.060	0.0	0.0	0.0	0.0	0.0	0.0	3.074	
3633	2.714	0.0	0.0	0.0	0.0	0.0	0.0	2.143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.357	
3634	0.418	0.227	0.041	0.0	0.0	0.0	0.0	0.455	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.581	
3639	0.292	0.042	0.0	0.0	0.0	0.0	0.0	0.417	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.762	
3641	1.399	0.0	0.0	0.0	0.0	1.734	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.193	
3642	0.878	0.022	0.001	0.0	0.0	0.167	0.0	0.339	0.021	0.002	0.0	0.0	0.0	0.0	0.0	1.470	
3643	1.062	0.022	0.0	0.062	0.043	0.0	0.0	0.037	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.246	
3644	0.618	0.752	0.0	0.0	0.0	0.472	0.0	1.419	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.261	
3649	0.518	0.259	0.0	0.0	0.0	0.518	0.0	0.135	0.338	0.0	0.0	0.0	0.0	0.0	0.0	1.768	
3652	0.276	0.0	0.0	0.0	0.0	0.0	0.0	0.400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.276	
3661	0.235	0.049	0.0	0.0	0.0	0.0	0.0	0.359	0.597	0.0	0.0	0.0	0.0	0.0	0.0	1.204	
3662	0.736	0.205	0.0	0.0	0.0	0.014	0.055	0.677	0.020	0.014	0.0	0.0	0.0	0.0	0.0	1.715	
3672	0.444	0.0	0.0	0.0	0.0	0.556	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.460	

SIC NO	PAPER	WOOD	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FERROUS	NUMFER	PETROL/ PAINTS	CHEM	SANIT/ ASHES	OTHER	SLUDGE	TOTAL	SOURCE
3955	3.435	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.435	
3961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.235	0.0	1.235	
3962	2.056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.056	
3963	0.332	0.0	0.0	1.639	0.0	0.0	2.594	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.565	
3964	4.545	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.136	0.0	0.0	0.0	0.0	0.0	4.681	
3991	0.392	13.164	0.0	0.733	0.0	0.0	0.0	0.296	0.0	0.0	0.0	0.0	0.0	0.0	14.777	
3993	0.956	0.651	0.067	0.425	0.0	0.036	0.0	0.621	0.077	0.004	0.0	0.0	0.0	0.0	2.537	
3994	0.130	0.242	0.320	0.0	0.0	0.0	0.0	0.044	0.003	0.0	0.0	0.0	0.0	0.0	0.434	
3996	0.250	0.0	0.0	0.0	0.0	0.0	0.0	1.591	0.0	0.0	0.234	0.0	22.746	0.0	24.621	
3999	0.260	0.165	0.156	0.035	0.0	0.0	0.0	0.110	0.015	0.0	0.0	0.0	1.330	0.0	2.071	

*Note to Appendix G

The set of "best choice" waste generation coefficients appearing in this table includes data from the Texas and Kentucky surveys for certain four-digit sectors where adequate data could not be obtained from firms in the Philadelphia area. These sectors are identified by either "T" or "K" in the column labeled "source." The inclusion of these additional data expands the total number of four-digit sectors covered to 396, of which 50 industries are represented by Texas data and 13 by Kentucky data.

Sectors which are omitted and sectors for which all coefficients are zero, are sectors for which information is not available.

IV. SOLID WASTE GENERATION COEFFICIENTS: NON-MANUFACTURING SECTORS*

Waste generation rates for the entire range of non-manufacturing economic sectors, including agriculture, forestry, mining, construction, transportation, wholesale trades, retail trades, and services are summarized in this paper. The information was developed for use in RSRI input-output studies of the economic and environmental impacts of alternative solid waste disposal systems and recycling programs. It may also be useful in a variety of planning applications for predicting waste generation and environmental modelling.

Information on waste generation has been compiled from a number of published and unpublished sources. Detailed studies of the waste generation characteristics for particular activities such as hospitals and households have been done, in addition to several reports that included estimates of waste generation rates for many industries. No single source covered all relevant industries, however, and some were more detailed and accurate than others. An attempt has been made here to construct the most complete, accurate, and detailed set of waste generation coefficients possible based on the best available data.

The information is presented according to the Regional Industrial Study classifications used in the Philadelphia Regional Input-Output Model, which correspond to SIC industrial categories. Two categories of sources are referenced for each industry. The first indicates the source of data on total waste generation for the sector and the second indicates the source of information used to specify the types of waste materials that make up the

*Chapter IV written by Thomas Kontuly.

total for each industry. In some cases more than one data source was used to derive the maximum amount of detail and accuracy possible.

All of the rates are expressed in tons of refuse generated per employee per year except RIS 9888, Households, which shows both tons per dollar income and tons per capita. It is assumed that each person in the Philadelphia SMSA generates 3.5 lbs. of household waste per day.

For purposes of comparison, the following table summarizes average total waste rates for the major subdivisions of the Philadelphia economy. Table 2 presents waste generation coefficients for more detailed categories of non-manufacturing activities specifying the type of refuse materials.

Table 1
SUMMARY OF WASTE GENERATION RATES

Average Total Tons of Waste/ Employee/Year (weighted by <u>employment</u>)	
Agriculture, Forestry & Fisheries	2.31
Mining	4.61
Contract Construction	18.23
Manufacturing	5.07
Transportation, Communication, Electric, Gas & Sanitary Services	4.76
Wholesale and Retail Trade	2.16
Finance, Insurance & Real Estate Services	.49
Government	1.96
	.54

Table 2
SOLID WASTE GENERATION COEFFICIENTS, NON-MANUFACTURING INDUSTRIES (TONS/EMP/YEAR)

RIS NO	PAPER	WOOD	TEXTILE	PLASTIC	RUBBER	GLASS	FIBER	FERRUS	NUMBER	PAINTS	CHEM	SAND/ ASHES	OTHER	TOTAL	DATA SOURCES	
															TOTAL AMONG TYPES	DISTRIBUTION
123	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.167	0.167	2	8
132	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.167	0.167	2	8
133	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.167	0.167	2	8
150	0.0	0.294	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.167	0.461	2	2 6 8
7 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.412	0.412	2	8
8 9	0.0	0.212	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.212	2	8
1411	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.461	0.461	2	1
1421	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.461	0.461	2	1
1441	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.461	0.461	2	1
1490	0.0	0.0	0.0	0.042	0.242	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.461	2	1
1511	0.040	0.073	0.0	0.165	0.165	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.170	0.770	1	1
1511	0.0	0.010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1	1
1621	0.0	0.023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1	1
17 1	0.072	0.028	0.007	0.066	0.036	0.071	0.0	0.025	0.017	0.0	0.015	0.0	0.362	0.609	1	1
1711	0.022	0.023	0.0	0.0	0.0	0.010	0.0	0.030	0.026	0.0	0.0	0.0	0.243	0.383	162	1 6 2
1731	0.020	0.010	0.0	0.010	0.0	0.0	0.0	0.020	0.040	0.0	0.0	0.0	0.180	0.280	162	1
19 0	0.060	0.013	0.0	0.0	0.0	0.0	0.010	0.040	0.0	0.0	0.010	0.0	0.060	0.140	1	1
4311	0.062	0.223	0.057	0.0	0.029	0.088	0.0	0.060	0.0	0.000	0.0	0.0	0.0	0.000	1	1 6 3
4111	0.051	0.037	0.046	0.0	0.037	0.077	0.0	0.038	0.0	0.002	0.0	0.0	0.0	0.241	2	5
4121	0.022	0.003	0.019	0.0	0.003	0.030	0.0	0.025	0.0	0.001	0.0	0.0	0.0	0.103	2	5
4190	0.024	0.003	0.021	0.0	0.004	0.033	0.0	0.027	0.0	0.001	0.0	0.0	0.0	0.113	162	1 6 3

*RIS Sector Code Numbers are identified in list following this table.

RIS NO	PAPER	WOOD	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FERROUS	NONFER	PAINTS	CHEM	SAND/ ASHES	DATA SOURCES		TOTAL	DISTRIBUTIO AMONG TYPES
													OTHER	TOTAL		
4210	C-258	2-072	0-2	2-311	0-0	C-0	C-2	0-011	0-0	0-0	0-0	0-0	0-0	0-142	1	1 1 6 5
4220	0-159	0-052	0-090	0-0	0-0	0-0	0-324	0-035	0-0	0-0	0-0	0-0	0-0	0-688	1	1 1 6 5
440	0-030	0-0	0-2	0-2	0-0	0-0	0-0	0-033	0-0	0-0	0-0	0-0	0-0	0-063	1	1 1 6 5
450	0-119	0-032	0-2	0-0	0-0	0-0	0-0	0-086	0-031	0-0	0-0	0-0	0-0	0-233	1 6 2	1 1 2 6 5
4811	0-238	0-0	0-0	0-2	0-035	0-0	0-0	0-035	0-0	0-005	0-0	0-0	0-0	0-253	2	2 2 6 5
4832	0-219	0-2	0-2	0-0	0-031	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-020	2	2 2 6 5
4833	0-219	0-0	0-2	0-2	0-031	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-020	2	2 2 6 5
4590	0-019	0-0	0-2	0-2	0-001	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-020	2	2 2 6 5
4911	0-162	0-0	0-0	0-0	0-032	0-0	0-0	0-019	0-0	0-004	0-003	0-0	1-783	1-973	3	3 6 5
4920	0-257	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-097	3	3 6 5
4941	0-149	0-0	0-0	0-0	0-004	0-0	0-0	0-0	0-0	0-203	0-096	0-0	0-0	0-252	2	2 2 6 5
4970	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-143	0-0	0-0	0-0	0-0	21-114	21-237	2	2 2 6 5
5012	0-000	0-002	0-0	0-002	0-225	0-0	0-0	0-099	0-0	0-0	0-0	0-0	0-061	0-639	2	2 2 6 5
5013	0-016	0-0	0-0	0-0	0-001	0-0	0-0	0-023	0-0	0-0	0-0	0-0	0-013	0-097	2	2 2 6 5
5014	0-216	0-0	0-0	0-0	0-001	0-0	0-0	0-020	0-0	0-0	0-0	0-0	0-013	0-097	2	2 2 6 5
5022	0-035	0-002	0-0	0-010	0-0	0-012	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-074	2 6 10	2 6 10
5028	0-035	0-002	0-0	0-010	0-0	0-012	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-074	2 6 10	2 6 10
5029	0-035	0-002	0-0	0-010	0-0	0-012	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-074	2 6 10	2 6 10
5032	0-009	0-0	0-0	0-0	0-0	0-0	0-0	0-007	0-0	0-0	0-0	0-0	0-0	0-074	2	2 2 6 5
5035	0-009	0-0	0-0	0-0	0-0	0-0	0-0	0-007	0-0	0-0	0-0	0-0	0-0	0-074	2	2 2 6 5
5039	0-009	0-0	0-0	0-0	0-0	0-0	0-0	0-007	0-0	0-0	0-0	0-0	0-0	0-074	2	2 2 6 5
5042	0-035	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5043	0-035	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5044	0-035	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5045	0-035	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5046	0-215	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5047	0-215	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5048	0-215	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5049	0-215	0-013	0-0	0-0	0-0	0-0	0-008	0-004	0-0	0-0	0-0	0-0	0-0	0-063	2 6 10	2 6 10
5051	0-002	0-0	0-0	0-0	0-0	0-0	0-001	0-001	0-0	0-0	0-0	0-0	0-0	0-001	2	2 2 6 5
5062	0-002	0-002	0-001	0-001	0-005	0-001	0-001	0-001	0-001	0-001	0-001	0-001	0-001	0-007	2	2 2 6 5

RIS NO	PAGE	4000	TEXTILE	PLSTIC	RUMBER	GLASS	FOUR	FREQUIS	NUMBER	PAINTS	CHEM	SAND/ ASHES	UTHERA	TOTAL	DATA SOURCES		DISTRIBUTION AMONG TYPES
															TOTAL		
5063	0.067	0.032	0.001	0.001	0.005	0.001	0.001	0.005	0.0	0.0	0.0	0.0	0.014	0.007	2		4
5064	0.067	0.032	0.001	0.001	0.005	0.001	0.001	0.005	0.0	0.0	0.0	0.0	0.014	0.007	2		4
5065	0.067	0.032	0.001	0.001	0.005	0.001	0.001	0.005	0.0	0.0	0.0	0.0	0.014	0.007	2		4
5072	0.137	0.064	0.001	0.001	0.010	0.001	0.001	0.010	0.0	0.0	0.0	0.0	0.034	0.019	2		4
5074	0.137	0.064	0.001	0.001	0.010	0.001	0.001	0.010	0.0	0.0	0.0	0.0	0.034	0.019	2		4
5077	0.137	0.064	0.001	0.001	0.010	0.001	0.001	0.010	0.0	0.0	0.0	0.0	0.034	0.019	2		4
5082	0.253	0.032	0.0	0.0	0.004	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.013	0.007	2		4
5083	0.053	0.032	0.0	0.0	0.004	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.013	0.007	2		4
5086	0.053	0.032	0.0	0.0	0.004	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.013	0.007	2		4
5087	0.053	0.032	0.0	0.0	0.004	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.013	0.007	2		4
5089	0.053	0.032	0.0	0.0	0.004	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.013	0.007	2		4
5091	0.112	0.032	0.001	0.001	0.004	0.001	0.001	0.004	0.0	0.0	0.0	0.0	0.029	0.016	2		4
5092	0.112	0.032	0.001	0.001	0.004	0.001	0.001	0.004	0.0	0.0	0.0	0.0	0.029	0.016	2		4
5093	0.112	0.032	0.001	0.001	0.004	0.001	0.001	0.004	0.0	0.0	0.0	0.0	0.029	0.016	2		4
5099	0.112	0.032	0.001	0.001	0.004	0.001	0.001	0.004	0.0	0.0	0.0	0.0	0.029	0.016	2		4
5210	0.208	0.032	0.001	0.001	0.015	0.001	0.001	0.015	0.0	0.0	0.0	0.0	0.031	0.019	2	2	4
5221	0.079	0.002	0.001	0.001	0.006	0.001	0.001	0.006	0.0	0.0	0.0	0.0	0.018	0.011	4		4
5241	0.079	0.002	0.001	0.001	0.006	0.001	0.001	0.006	0.0	0.0	0.0	0.0	0.018	0.011	4		4
5250	0.079	0.002	0.001	0.001	0.006	0.001	0.001	0.006	0.0	0.0	0.0	0.0	0.018	0.011	4		4
5311	0.084	0.036	0.001	0.001	0.010	0.001	0.001	0.010	0.0	0.0	0.0	0.0	0.011	0.012	4		4
5331	0.084	0.036	0.001	0.001	0.010	0.001	0.001	0.010	0.0	0.0	0.0	0.0	0.011	0.012	4		4
5342	0.039	0.002	0.0	0.0	0.002	0.001	0.001	0.002	0.0	0.0	0.0	0.0	0.004	0.006	3		4
5351	0.102	0.034	0.001	0.001	0.004	0.001	0.001	0.004	0.0	0.0	0.0	0.0	0.012	0.015	4		4
5390	0.102	0.034	0.001	0.001	0.004	0.001	0.001	0.004	0.0	0.0	0.0	0.0	0.012	0.015	4		4
5411	0.237	0.025	0.0	0.004	0.0	0.0	0.001	0.025	0.0	0.0	0.0	0.0	0.017	0.023	4	10	9
5420	0.237	0.025	0.0	0.004	0.0	0.0	0.001	0.025	0.0	0.0	0.0	0.0	0.017	0.023	4	10	9
5431	0.237	0.025	0.0	0.004	0.0	0.0	0.001	0.025	0.0	0.0	0.0	0.0	0.017	0.023	4	10	9
5441	0.237	0.025	0.0	0.004	0.0	0.0	0.001	0.025	0.0	0.0	0.0	0.0	0.017	0.023	4	10	9
5460	0.237	0.025	0.0	0.004	0.0	0.0	0.001	0.025	0.0	0.0	0.0	0.0	0.017	0.023	4	10	9
5490	0.237	0.025	0.0	0.004	0.0	0.0	0.001	0.025	0.0	0.0	0.0	0.0	0.017	0.023	4	10	9
5511	0.038	0.0	0.0	0.0	0.022	0.0	0.0	0.022	0.0	0.0	0.0	0.0	0.005	0.026	3		4
5521	0.038	0.0	0.0	0.0	0.022	0.0	0.0	0.022	0.0	0.0	0.0	0.0	0.005	0.026	3		4
5531	0.067	0.001	0.0	0.001	0.004	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.006	0.021	2		4
5541	0.103	0.0	0.0	0.0	0.058	0.0	0.001	0.058	0.0	0.0	0.0	0.0	0.018	0.021	4		4
5599	0.103	0.0	0.0	0.0	0.058	0.0	0.001	0.058	0.0	0.0	0.0	0.0	0.018	0.021	4		4
5610	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.012	0.039	4		4

RIS NO	PAPER	WTCO	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FERRUS	MUMFER	METAL/PAINTS	CHEM	SAND/ASHES	OTHER	TOTAL	DATA SOURCES	
															TOTAL	DISTRIBUTION AMONG TYPE
5621	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.012	0.059	4	4
5630	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.012	0.059	4	4
5641	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.012	0.059	4	4
5651	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.012	0.059	4	4
5660	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.012	0.059	4	4
5690	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.012	0.059	4	4
5710	0.178	0.048	0.001	0.001	0.0	0.0	0.0	0.032	0.0	0.0	0.0	0.0	0.015	0.240	4	4
5722	0.178	0.048	0.001	0.001	0.0	0.0	0.0	0.032	0.0	0.0	0.0	0.0	0.015	0.240	4	4
5730	0.178	0.048	0.001	0.001	0.0	0.0	0.0	0.032	0.0	0.0	0.0	0.0	0.015	0.240	4	4
5812	0.240	0.0	0.016	0.004	0.0	0.033	0.238	0.045	0.0	0.0	0.0	0.0	0.012	0.403	2	4
5813	0.215	0.0	0.001	0.0	0.0	0.016	0.014	0.033	0.0	0.0	0.0	0.0	0.035	0.094	4	4
5912	0.133	0.001	0.001	0.0	0.032	0.004	0.020	0.034	0.0	0.0	0.0	0.0	0.020	0.185	4	4
5921	0.275	0.002	0.001	0.001	0.004	0.0	0.003	0.032	0.0	0.0	0.0	0.0	0.015	0.133	4	4
5940	0.275	0.002	0.001	0.001	0.004	0.0	0.003	0.032	0.0	0.0	0.0	0.0	0.015	0.133	4	4
5950	0.275	0.002	0.001	0.001	0.004	0.0	0.003	0.032	0.0	0.0	0.0	0.0	0.015	0.133	4	4
5971	0.275	0.002	0.001	0.001	0.004	0.0	0.003	0.032	0.0	0.0	0.0	0.0	0.015	0.133	4	4
5980	0.275	0.002	0.001	0.001	0.004	0.0	0.003	0.032	0.0	0.0	0.0	0.0	0.015	0.133	4	4
5990	0.275	0.002	0.001	0.001	0.004	0.0	0.003	0.032	0.0	0.0	0.0	0.0	0.015	0.133	4	4
6011	0.050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.050	2	5
6020	0.021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.021	2	5
6030	0.050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.050	2	5
6120	0.049	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.049	2	5
6190	0.050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.050	2	5
6200	0.036	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.036	2	5
6310	0.050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.050	2	5
6310	0.062	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.062	2	5
6560	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.461	0.461	2	2

MIS NO	PAPER	WOOD	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FIBROUS	NUMER	PAINTS	CHEM	SAND/ ASHES	OTHER	TOTAL	DATA SOURCES	
															TOTAL	DISTRIBUTION ANNUAL TYPE
6590	6.050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.050	2	5
720	0.007	0.0	0.007	0.0	0.051	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.066	2	5
731	0.073	0.0	0.052	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.002	0.0	0.0	0.075	2	5
7310	0.060	0.0	0.002	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.0	0.064	2	5
740	0.073	0.0	0.002	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.002	0.0	0.0	0.078	2	5
750	0.006	0.0	0.0	0.0	0.008	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.064	2	5
790	0.007	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.151	2 & 10	5
8261	0.026	0.0	0.0	0.0	0.001	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.084	2	5
8290	0.064	0.0	0.0	0.0	0.002	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.109	0.219	2	5
8211	0.0284	0.0	0.0	0.0	0.002	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.066	0.178	2	5
8220	0.061	0.0	0.0	0.0	0.0	0.008	0.0	0.0	0.0	0.0	0.0	0.0	0.019	0.108	2	5
8290	0.036	0.0	0.0	0.0	0.002	0.046	0.0	0.0	0.0	0.0	0.0	0.0	0.115	0.244	2	5
8466	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.044	2	2
880	0.091	0.004	0.004	0.003	0.003	0.014	0.027	0.014	0.0	0.0	0.0	0.0	0.021	0.181	2	7

ITEMS NO	DATA SOURCES													DISTRIBUTION TOTAL AMONG TYPES	
	PAPER	WOOD	TEXTILE	PLSTIC	RUBBER	GLASS	FOOD	FERRUS	NONFER	PETROL/ PAINTS	SAND/ ASHES	OTHER	TOTAL		
9135	0.026	0.0	0.0	0.0	0.001	0.018	0.0	0.0	0.0	0.0	0.0	0.044	0.089	6	5
9136	0.119	0.002	0.0	0.0	0.0	0.0	0.0	0.086	0.031	0.0	0.0	0.0	0.238	6	1, 2 & 3
9137	0.031	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.034	6	2
93 9	0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.015	2	2
4988	1.211	0.048	0.048	0.036	0.036	0.193	0.364	0.193	0.0	0.0	0.0	0.291	2.420	6	7
**9588	3.018	0.121	0.121	0.093	0.090	0.483	0.905	0.483	0.0	0.0	0.0	0.724	6.035	6	7

* Tons x 10⁻¹ per \$1000 income.

** Tons x 10⁻¹ per capita.

REGIONAL INTERINDUSTRY STUDY
SECTOR DEFINITIONS FOR
NON-MANUFACTURING INDUSTRIES

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
<u>AGRICULTURE, FORESTRY & FISHERIES</u>		
0120	Fruit & Vegetable Products	0122 ,0123
0132	Dairy Products	0132
0133	Poultry Products	0133, 0134
0190	Other Agricultural Products	011, 0135, 0136, 014, 019, 0729 pt, 021
0708	Agricultural, Forestry, & Fishery Services	071, 0723, 0729 pt, 085, 098
0809	Forestry & Fishery Products	074, 081, 082, 084, 086, 091
<u>MINING</u>		
1411	Dimension Stone	1411
1421	Crushed & Broken Stone	142
1441	Sand & Gravel	144
1490	Mining, not elsewhere classified	145, 148, 149
<u>CONSTRUCTION</u>		
1509	Maintenance & Repair Construction Allocator	(NA)
1511	General Contractors	1511
1611	Highway & Street Construction	1611
1621	Heavy Construction	1621
1701	Special Trade Contractors, not elsewhere classified	172, 174, 175, 176, 177, 178, 179
1711	Plumbing, Heating, & Air Conditioning Contractors	1711
1731	Electrical Contractors	1731
6560	Residential Contractors, Developers, Builders, etc.	6551, 6561

TRANSPORTATION, COMMUNICATIONS, ELECTRIC, GAS
AND SANITARY SERVICES

<u>Sector Code</u>		
4010	Railroads	4011, 4013
4111	Local & Suburban Transit	4111
4121	Taxicabs	4121
4210	Trucking, Local & Long Distance	421
4220	Public Warehousing	422
4400	Water Transportation	44
4500	Air Transportation	45

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
<u>TRANSPORTATION, COMMUNICATIONS, ELECTRIC, GAS AND SANITARY SERVICES - Cont.</u>		
4190	Transportation Services, not elsewhere classified	4020, 4041, 4119, 413, 414, 415, 417, 4231, 46, 47.
4811	Telephone Communication	4811
4832	Radio Broadcasting	4832
4833	Television Broadcasting	4833
4890	Communication Services, not elsewhere classified	4821, 4899
4911	Electric Companies & Systems	4961, 4911, 4931 pt
4920	Gas Companies & Systems	492, & 4932 pt
4941	Water Supply	4941
4990	Sanitary & Other Utility Systems, not elsewhere classified	4939, 495, 497
<u>WHOLESALE TRADE</u>		
5012	Automobiles & Other Motor Vehicles	5012
5013	Automotive Equipment	5013
5014	Tires & Tubes	5014
5022	Drugs, Drug Proprietaries, & Druggists' Sundries	5022
5028	Paints & Varnishes	5028
5029	Chemicals & Allied Products, not else- where classified	5029
5032	Dry Goods, Piece Goods, & Notions	5033, 5034
5035	Apparel & Accessories, Hosiery, & Lingerie	5036, 5037

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
	<u>WHOLESALE TRADE</u>	
5039	Footwear	5039
5041	Groceries, General Line	5041
5043	Dairy Products	5043
5044	Poultry & Poultry Products	5044
5045	Confectionery	5045
5046	Fish & Sea Foods	5046
5047	Meats & Meat Products	5047
5048	Fresh Fruits & Vegetables	5048
5049	Groceries & Related Products, not elsewhere classified	5049, 5042
5051	Farm Products, Raw Materials	505
5063	Electrical Apparatus & Equipment, Wiring Supplies, & Construction Materials	5063
5064	Electrical Appliances, TV & Radio Sets	5064
5065	Electronic Parts & Equipment	5065
5072	Hardware	5072
5074	Plumbing & Heating Equipment & Supplies	5074
5077	Air Conditioning & Refrigeration Equip- ment & Supplies	5077
5082	Commercial & Industrial Machinery, Equipment, & Supplies	5082
5083	Farm Machinery & Equipment	5083
5086	Professional Equipment & Supplies	5086
5087	Equipment & Supplies for Service Es- tablishments	5087

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
<u>WHOLESALE TRADE</u>		
5089	Machinery, Equipment, & Supplies, not elsewhere classified	5088, 5089
5091	Metals & Minerals, Exc. petroleum & scrap	5091
5092	Petroleum & Petroleum Products	5092
5093	Scrap & Waste Materials	5093
5099	Miscellaneous Wholesalers, not elsewhere classified	5094, 5095, 5096, 5097, 5098, 5099.
<u>RETAIL TRADE</u>		
5210	Lumber & Other Building Materials Dealers	5211
5221	Plumbing, Heating, & Air Conditioning Equipment Dealers	5221
5231	Paint, Glass, & Wallpaper Stores	5231
5241	Electrical Supply Stores	5241
5250	Hardware Stores & Farm Equipment Dealers	525
5311	Department Stores	5311
5342	Mail Order Houses & Merchandise Vending Machine Operators	5341, 5321
5331	Variety Stores	5331
5351	Direct Selling Organizations	5351
5390	Miscellaneous General Merchandise Stores	5399
5411	Grocery Stores	5411
5420	Meat & Fish Markets	5421
5431	Fruit Stores & Vegetable Markets	5431

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
	<u>RETAIL TRADE</u>	
5441	Candy, Nut, & Confectionery Stores	5441
5460	Retail Bakeries	546
5490	Misc. Food Stores, not elsewhere classified	5451, 5499
5511	Motor Vehicle Dealers	5511
5521	Motor Vehicle Dealers, (used cars only)	5521
5531	Tire, Battery, & Accessory Dealers	5531
5541	Gasoline Service Stations	5541
5599	Misc. Aircraft, Marine & Automotive Dealers	559
5610	Men's & Boys' Clothing & Furnishings Stores	5611
5621	Women's Ready-to-Wear Stores	5621
5630	Women's Accessory & Specialty Stores	5631
5641	Children's & Infants' Wear Stores	5641
5651	Family Clothing Stores	5651
5660	Shoe Stores	5661
5690	Misc. Apparel & Accessory Stores, not elsewhere classified	5671, 5681, 5699
5710	Furniture, Home Furnishings, & Equip- ment Stores	571
5722	Household Appliance Stores	5722
5730	Radio, Television, & Music Stores	573
5812	Eating Places	5812
5813	Drinking Places	5813
5912	Drug Stores & Proprietary Stores	5912

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
<u>RETAIL TRADE</u>		
5921	Liquor Stores	5921
5940	Book & Stationery Stores	594
5950	Sporting Goods Stores & Bicycle Shops	595
5971	Jewelry Stores	5971
5980	Fuel & Ice Dealers	598
5990	Retail Stores, not elsewhere classified	593, 596, 599
<u>FINANCE, INSURANCE, AND REAL ESTATE</u>		
6011	Federal Reserve Bank	6011
6020	Commercial & Stock Savings Banks	602
6030	Mutual Savings Banks	603
6120	Savings & Loan Associations	612
6190	Miscellaneous Financial Institutions	604, 605, 611, 613, 614, 615, 616, 67
6200	Security & Commodity Brokers, Dealers, Exchanges, & Services	62
6301	Non-Life Insurance Carriers	632 pt, 633, 635, 636, 639
6310	Life Insurance Carriers	631, 632 pt.
6590	Real Estate, Insurance, & Com- bination Agents	64, 651, 653, 66
<u>SERVICES</u>		
7200	Hotel, Personal, & Repair Services	70, 72, 76, (exc. 7694, 7699)
730	Business Services, exc. Advertising	6541, 73, (exc. 731, 7391) 7694, 7699, 81, 89, (exc. 8921).

<u>Sector Code</u>	<u>Title</u>	<u>SIC</u>
	<u>SERVICES</u>	
7310	Advertising Services	731
7400	Research & Development, Educational & Scientific Research Agencies	7391, 8921
7500	Automobile Repair, Services, & Garages	75
7900	Amusement & Recreational Services	78, 79
8061	Hospitals	8061
8090	Medical & Health Services, not else- where classified	80 (except 8061), 0722
8211	Elementary & Secondary Schools	8211
8220	Institutions of Higher Education	822
8290	Other Educational Services, not else- where classified	823, 824, 829
8486	Non-Profit Membership Organizations, Museums, Art Galleries, Botanical & Zoological Gardens	84, 86
8800	Private Household Services	88
9300	Local Government	93
9826	Office Supplies Allocator	NA
9842	Transportation Services Allocator	NA

Data Sources

1. Texas Industrial Survey - printouts of the results were supplied by Mr. Ron Talley and Mr. Dan Greathouse of the E.P.A.
2. Roy F. Weston, Inc. "Solid Waste Generation Rates, Baltimore Region." West Chester, Pa., n.d. (mimeographed).
3. Pennsylvania Survey of Industrial Establishments 1969 - results were supplied by the Penna. Department of Environmental Resources, Harrisburg, Pa.
4. Environmental Systems Division, URS Research Company. "A Planning Model for the Prediction of Residential and Commercial Solid Wastes," Final Report prepared for the Office of Solid Waste Management Programs, E.P.A., San Mateo, Calif., June 1972 (mimeographed).
5. Cumberland, John H. and Korbach, Robert J. "A Regional Interindustry Environmental Model." Bureau of Business and Economic Research, University of Maryland, College Park, Maryland, November 1972.
6. Author's estimate, based on similar sectors.
7. Salvato, Joseph A. Jr. Environmental Engineering and Sanitation. New York: Wiley Interscience, 1972.

Data Sources

8. California State Department of Public Health. "California Solid Waste Managements Study (1968) and Plan (1970)," prepared for the Office of Solid Waste Management E.P.A., Berkeley, Calif., 1971.
9. SRS Engineers. "Solid Waste Management in Retail Food Stores," Final Report prepared for the Food Distribution Laboratory, U.S. Department of Agriculture, Long Beach, Calif., August 1973 (mimeographed).
10. Data supplied by Mr. Lawrence Burch of the Solid Waste Management Board, State of California, January 1974.

Bibliography

Isard, Walter, Langford, T.W., and Romanoff. "The Philadelphia Region Input-Output Study." Philadelphia: Regional Science Research Institute, 1967.

U.S. Bureau of Census. 1968 County Business Patterns. Washington, D.C.: U.S. Government Printing Office, December 1969.

IV. PRODUCTION FUNCTIONS FOR SOLID WASTE DISPOSAL*

Introduction

The RSRI has been studying the use of input-output techniques in regional solid waste management planning and, more specifically, working towards the empirical implementation of an environmental-economic system that integrates waste generation, disposal and recycling activities into a model of the Philadelphia SMSA economy. The model would be useful in projecting waste disposal requirements of the region and in evaluating the economic and environmental impacts of alternative disposal systems, recycling programs, and economic trends (Steiker, [1974]).

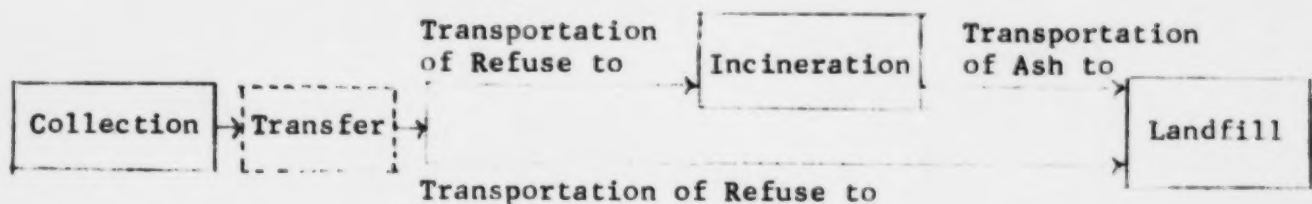
Much of the data necessary to carry out such studies has been assembled, including a comprehensive set of waste generation coefficients for economic sectors at the four- and three-digit SIC levels disaggregated by type of waste material (Steiker, [1973] and Kontuly, [1974]). In addition, implementation of the model requires detailed information on the costs per ton of waste disposal, specifying the type of inputs necessary for various solid waste disposal processes in order to construct input-output type production functions for waste disposal activities. The information available on actual municipal waste disposal costs in the Philadelphia SMSA is presented in this paper in a form suitable for input-output analysis.

*Chapter V written by Thomas Kontuly.

Waste Disposal Activities

The disposal of solid waste actually involves a combination of collection, transportation, and final disposal processes. Diagram 1 illustrates the disposal activities practiced in the Philadelphia area. Collection involves picking up refuse and placing it in a vehicle. Refuse is then transported to a disposal site. The disposal system may include transfer stations, which are break-in-bulk points at which refuse is transferred from smaller to larger vehicles in order to reduce transportation costs. Final disposal is normally accomplished either by land-filling or incineration. When incineration is used, residue ash must be transported to landfills.

DIAGRAM 1: SOLID WASTE DISPOSAL PROCESSES



Specific disposal systems may utilize various combinations of these processes. In the Philadelphia area at the present time, for example, transfer stations are not generally used, and are never found in combination with incineration. Since each process has different cost characteristics, separate production functions were developed for waste collection, transportation, transfer station, incineration, and landfilling.

Data Sources

Actual waste disposal costs for the Philadelphia area were considered most desirable for the purposes of the RSRI study. Consequently, the data in this report were compiled from budgets and reports of municipalities in the Philadelphia SMSA. Unfortunately, only a limited amount of information was available since many communities in suburban counties contract with private firms to provide waste disposal services and therefore do not compile detailed records on waste disposal costs.

In addition, difficulties were encountered in comparing disposal costs in various municipalities for which data were available due to differences in accounting procedures. Basically two types of accounting systems were found to be used by public agencies in the Philadelphia metropolitan area. The City of Philadelphia employs a total cost accounting system, which allocates all costs to the appropriate public service. (Many costs, however, are consolidated and cannot be identified specifically in the total for each service provided for the public.)

The accounting systems of many smaller suburban municipalities

are established along budgetary lines and little effort is made to compile information on the total costs of individual public services. The budgets record costs directly incurred by the department concerned with waste disposal but provide no basis to allocate additional costs associated with assisting departments such as vehicle maintenance. Also, many municipal budgets did not include depreciation of capital equipment but merely recorded costs incurred during a particular year.

Consequently, it was necessary to analyze carefully the few observations available to ascertain sufficiently detailed and complete estimates of waste disposal costs. The cost estimates, however, are based on the best available information and generally the data were found to be internally consistent and within the range of other estimates of disposal costs.

Data on the costs of collection, incineration, and landfilling were available for Philadelphia from reports of the Department of Streets. The municipal budgets of Upper Darby and Haverford Townships provided representative information for collection costs in suburban communities. Additional data on incineration and transfer stations were found in the Annual Report of the Delaware County Disposal Department. Montgomery County data on landfilling operations were obtained from the Director of the Solid Waste Management System and the 1973 Solid Waste Fund Budget.

Collection and Transportation

Collection and transportation costs per ton of solid waste disposal by expenditure category for the city of Philadelphia, Upper Darby Township and Haverford Township are shown in Table 1. At first glance, expenditures in Upper Darby and Haverford appear to be roughly comparable while collection and transportation costs in Philadelphia seem to be significantly higher. This discrepancy may be explained by higher labor costs in the City of Philadelphia and the omission of certain costs in the Haverford and Upper Darby accounting reports.

Labor is the most important cost component in the collection and transportation of solid waste. Table 2 compares labor costs for Philadelphia and Upper Darby Township. Starting salaries of laborers and drivers in the Philadelphia Department of Sanitation are \$1000 a year higher than wages paid to comparable employees in Upper Darby and this is reflected in direct labor costs, which are \$3 higher per ton of waste disposal for Philadelphia. In addition, paid leave is substantially higher for Philadelphia and indirect labor expenses for such items as custodial, clerical and security services do not appear in the records for Upper Darby.

Also, the Upper Darby figure of \$1.02 per ton for vehicle maintenance reflects only costs of materials. The township was unable to assign labor and other costs associated with vehicle maintenance to different functions. A detailed breakdown of solid waste collection vehicle maintenance costs was available for Philadelphia and is shown as Table 3.

TABLE 1

COMPARISON OF COLLECTION AND TRANSPORTATION COSTS, FY 1972 (\$/TON)

	Haverford Township	Upper Darby Township	Philadelphia County
Building Maintenance			\$.0400
Work Clothing	\$.1346	\$.0543	
Publishing	.0049		
Gasoline and Oil	.2393	.4345	.2900
Plastic	.2393		
Metal Cans		.1086	
Telephone		.0087	
Vehicle Insurance	.3185	.5432	
Business Services		.2172	
Advertising		.0217	
Vehicle Repair	.5383	1.0247	2.9700
Administration			.7500
Wages	10.4585	10.4304	18.4100
Vehicle Depreciation	1.2202	1.2514	.9100
Employee Fringe Benefits	<u>1.3880</u>	<u>2.0093</u>	<u>1.9300</u>
Total	\$14.5416	\$16.1041	\$25.3000

TABLE 2

COMPARISON OF LABOR COSTS - COLLECTION, FY 1972 (\$/TON)

	Philadelphia County	Upper Darby Township
Direct Labor	\$11.46	\$8.46
Paid Leave		
(Vacation and Sick Leave)	3.35	1.19
Supervision	1.07	.78
Overtime	.76	-
Custodial	.20	-
Clerical	.16	-
Watchman	.11	-
Sign Erection	.08	-
Distribution of Circulars	.01	-
Other Indirect Labor	<u>1.21</u>	<u>-</u>
Total Labor Costs	\$18.41	\$10.43

TABLE 3

BREAKDOWN OF VEHICLE MAINTENANCE, COLLECTION, CITY OF PHILA
FY 1972 (\$ /TON)

Direct Labor	\$.68
Indirect Labor	.98
Fringe Benefits	.27
Direct Materials	.72
Indirect Materials	.02
Equipment Depreciation	.01
Electricity	.03
Vehicle Costs	.01
Depreciation Building	.04
Building Maintenance	.09
Other Utilities	.03
Administration	<u>.09</u>
Total Cost	2.97

Notice that the \$8 difference in labor costs and the \$2 difference in vehicle maintenance per ton that have been pointed out account for the difference in reported total collection and transportation cost of \$16.10 per ton reported for Upper Darby and \$25.30 per ton in Philadelphia.

The data have been combined to obtain a composite production function for refuse collection and transportation in the Philadelphia SMSA. Cost elements (e.g. building maintenance) reported for only one township or county and determined to be applicable to other areas were included in the composite estimate. Averages of other cost categories reported by more than one municipality were used to represent costs for the entire metropolitan area. The Standard Industrial Classification (SIC) numbers that identify sources of various supplies and services are compatible with the industrial categories in the Philadelphia Regional Input Output Model.

Table 4 represents the combined costs for the collection and transportation of solid waste. Collection may be defined as the process of workers and vehicles moving along the streets and deposit refuse into the vehicles. Transportation involves workers and collection vehicles traveling to disposal sites or transfer stations, dumping the refuse, and returning to a point on the collection route.

Since transportation costs vary for different areas and waste disposal systems, it was considered desirable to make a distinction between the two processes. Officials of the Philadelphia Department of Sanitation estimated that on the average, two hours are required to fill a collection vehicle and one hour to drive to either an incinerator or landfill site and return.

Without the benefit of more detailed empirical studies, the data in Table 4 divided into collection and transportation costs on the basis of this ratio of time spent in each activity. The result appears in Table 5.

Incineration

The procedure for constructing a production function for incineration is equivalent to the procedure used for collection. Incineration costs for Philadelphia and Delaware counties are presented in Table 6. Philadelphia costs are the costs of the East Central and Northwest incinerators. The Bartram, Southeast, Northeast, and Harrowgate incinerators are considered obsolete and are to be shut down in the near future. Therefore these costs are not included. Delaware County costs represent the cost of three incinerators that are currently in use. It should be noted that the number of incinerated tons is approximately equal for Philadelphia and Delaware counties.

The higher incineration costs in Philadelphia may be attributed, like collection costs, to the labor component and to discrepancies in accounting systems. Not only are wages higher in Philadelphia than in Delaware County, expenditures of \$3.71 per ton compared to \$2.84 per ton, but labor costs associated with vehicle maintenance, building maintenance, and administration are not reported by Delaware County. Again, depreciation of capital equipment is handled differently in the two counties. Representative incineration cost estimates were determined from the data, taking these differences into account, and appear in Table 7.

TABLE 4

COMPOSITE PRODUCTION FUNCTION FOR REFUSE COLLECTION AND TRANSPORTATION, PHILA. SMSA, FY 1972, (\$/TON)*

SIC		Cost	% of Total
1519	General Contractors	.0400	.001
2328	Work Clothing	.0944	.004
2711	Publishing	.0049	.000
2911	Gas	.2570	.012
2992	Grease	.0643	.003
3079	Plastic	.2393	.011
3461	Metal Stampings	.1086	.005
4811	Telephone	.0087	.000
6301	Non-Life Insurance	.4309	.021
7304	Business Services	.2173	.010
7310	Advertising	.0217	.001
7500	Vehicle Repair	1.5110	.074
9888	Wages	14.4250	.709
9892	Capital Allowance	1.1272	.055
9893	Empl. Fringe	<u>1.7758</u>	<u>.087</u>
Total		20.3261	1.000

* An additional step is necessary before this information may be used for input-output analysis. The appropriate trade margins indicating the demand for wholesale and retail trade services must be separated from certain categories of purchases.

TABLE 5

SEPARATE PRODUCTION FUNCTIONS FOR COLLECTION AND TRANSPORTATION
 ACTIVITIES: PHILA. SMSA FY 1972 (\$ /TON)

SIC		Phila. SMSA	
		Collection	Transportation
1511	General Contractors	.0268	.0132
2328	Work Clothing	.0632	.0312
2711	Publishing	.0033	.0016
2911	Gas	.1722	.0848
2992	Grease	.0431	.0212
3079	Plastic	.1603	.0790
3461	Metal Stampings	.0728	.0358
4811	Telephone	.0058	.0029
6301	Non-Life Insurance	.2887	.1422
7304	Business Services	.1456	.0717
7310	Advertising	.0145	.0072
7500	Auto Repair	1.0124	.4986
9888	Wages	9.6647	4.7603
9892	Capital Allowance	.7552	.3720
9893	Employee Fringe	1.1898	.5860
Total Phila. SMSA		13.6184	6.7077

TABLE 6

COMPARISON OF INCINERATION COSTS, FY 1972 (\$ /TON)

	Phila. County	Delaware County
Building Maintenance	.914	
Fuel	.020	
Heating Oil	.050	.030
Telephone and Postage		.009
Electricity	.250	.040
Water	.570	.190
Operating Supplies	.259	.212
Exterminators		.016
Equipment Rental		.311
Capital Investment Over \$300		.142
Equipment Maintenance and Repair	.372	.975
Capital Investment Under \$300		.002
Travel Expense		.002
Administration	.198	
Wages	3.228	2.838
Equipment and Vehicle Depreciation	.124	
Building Amortization	.747	
Interest on Bonded Debt	.222	
Employee Fringe Benefits (Not Included in Phila. Wages)	<u>.485</u>	<u> </u>
Total Cost/Ton	\$7.439	\$4.767
Tons Incinerated	390,707	376,510

TABLE 7

PRODUCTION FUNCTION FOR INCINERATION, PHILA. SMSA, FY 1972 (\$/TON)

SIC		PHILA. SMSA COST
1511	General Contractors	.914
2851	Paints	.157
2911	Gasoline	.020
2911	Heating Oil	.040
3011	Tires and Tubes	.157
3429	Hardware	.157
4811	Telephone	.009
4911	Electricity	.145
4941	Water	.380
7300	Business Services	.388
9888	Wages	3.033
9892	Capital Allowance	1.036
9893	Employee Fringe Benefits	<u>.485</u>
Total		6.921

Landfill Costs

Landfill costs for Philadelphia and Montgomery County are presented in Table 8. Normally there are three types of costs associated with a landfill. These are the costs of land acquisition, preparation of land, and costs of operation.

Notice that operating costs are approximately equal, \$1.33 per ton for Philadelphia and \$1.57 per ton in Montgomery County. Acquisition and preparation costs are quite different, however. Neither Philadelphia nor Montgomery County own the landfill sites that are used. The City of Philadelphia rents land in Pennsylvania and New Jersey. The rental paid includes charges for preparation as well as land rent.

Montgomery County has transformed an unused quarry into a landfill. The site is leased for a token amount (\$1 per year) so that acquisition costs are really not reported, which essentially accounts for the difference in total costs between Montgomery County and Philadelphia. Also, the construction costs for Montgomery County may not be truly representative. These were calculated on the basis of an estimated useful life of 5 years and total capacity of 500,000 tons for the facility, which was built in strict compliance with state environmental standards. Officials in the county indicated that future construction costs may be lower as environmental standards will be relaxed.

The data presented, nevertheless, represent the best information available on the actual cost of landfiling operations in the Philadelphia area and were therefore used to determine

the production function shown in Table 9. In combining the Philadelphia and Montgomery County data the figures for Montgomery County were adjusted to represent 1972 prices. Since the Montgomery County landfill meets stringent environmental standards the figures in Table 9 perhaps overestimate actual landfill costs, but may be taken as representative of "best practice" operations.

Land acquisition costs in many cases may not be true costs. If a local government takes a marginal piece of property, prepares it, uses it as a landfill and returns it as a park, the value of the property has increased rather than decreased, subsequent to its use as a landfill. The Montgomery County landfill is an example of such a case. However, improvements in land value could not be accurately estimated and are not included as a cost factor.

Transfer Station

The costs of operation for the Montgomery County transfer station appear as Table 10. This is the only transfer station in the Philadelphia area. The design capacity of this transfer station is 600 tons per 8 hours, or 150,000 tons per year. However, the actual level of operation is estimated to be 300 tons per day, or approximately 75,000 tons per year. Montgomery County engineers believe that design capacity will not be reached, and that operation will remain at 300 tons per day.

TABLE 8
COMPARISON OF LANDFILL COSTS (\$/TON)

	FY 1972	FY 1973
	Phila.	Montgomery
	County	County
Acquisition and Preparation Costs		
Landfill Rentals	2.61	
Construction Costs -		
Depreciation 5 Years		1.40
Operating Costs		
Materials and Supplies		.20
Fuel	.01	
Equipment Maintenance	.23	.20
Rental of Crane	.01	
Equipment Depreciation (5 Years)	.45	.45
Administration	.12	
Wages	.44	.64
Employee Fringe Benefits	.07	.08
Total Cost/Ton	\$3.94	\$1.57
Tons Landfilled	362,172	100,000

TABLE 9

PRODUCTION FUNCTIONS FOR LANDFILL, PHILADELPHIA SMSA, 1972, (\$/TON)

SIC		Cost
1511	General Contractors	1.33
2911	Gasoline	.01
3011	Tires and Tubes	.10
3429	Hardware	.10
6590	Real Estate Agents	1.28
7300	Business Services	.22
9888	Wages	.51
9892	Capital Allowance	.44
9893	Employee Fringe Benefits	.09
Total		4.08

TABLE 10

TRANSFER STATION COSTS, MONTGOMERY COUNTY (\$/TON)

	FY 1973 Montgomery County
Construction Cost - Depreciation (20 Yrs.)	.46
Materials and Supplies	.26
Equipment Maintenance	.52
Tractors and Trailers - Depreciation(5 Yrs.)	.38
Wages	1.31
Employee Fringe Benefits	.19
Total Cost/Ton	\$3.12
Tons Transferred	75,000

TABLE 11

PRODUCTION FUNCTION FOR TRANSFER STATION, PHILADELPHIA SMSA,
FY 1972 (\$/TON)

SIC		Cost
1511	General Contractors	.44
2911	Gasoline	.02
3011	Tires and Tubes	.11
3429	Hardware	.12
7300	Business Services	.49
9888	Wages	1.24
9892	Capital Allowance	.36
9893	Employee Fringe Benefits	.18
Total		2.96

A production function for the transfer station is presented in Table 11. The figures originally reported for 1973 have been adjusted to reflect 1972 prices.

Comparison of Disposal Costs in Large Cities

The data presented on disposal costs in Philadelphia are in line with such costs in other large cities. In Table 12 Philadelphia costs for Fiscal Year 1972 are compared to 1971 costs in New York City and San Francisco.

TABLE 12

COMPARISON OF URBAN WASTE DISPOSAL COSTS

	FY 1972 Philadelphia (\$/Ton)	1971 New York City (\$/Ton)	1971 San Francisco (\$/Ton)
Collection	25.30*	30-32	29
Incineration	6.92	7-8	
Landfilling	4.08	4	2

* The figure that appears represents collection costs for the City of Philadelphia (see Table 1).

Source for New York City and San Francisco: "The Economics of Recycling Waste Materials," Hearings Before the Subcommittee on Fiscal Policy - Joint Economic Committee, U.S. Government, November 8 and 9, 1971.

Collection costs in Philadelphia are slightly lower than comparable costs in San Francisco and New York City. Philadelphia incineration and landfill costs almost duplicate such costs in New York City. San Francisco landfills its refuse in a remote northern California county, thus its landfill costs are low.

Reservations on the Use of the Production Functions

When the production functions in this paper are applied to the various counties of the SMSA, an over-estimation of costs may result. In collection activities, Philadelphia costs are used to supplement costs of Upper Darby Township. The Philadelphia costs are high, and the use of these figures will tend to over-estimate collection costs in the SMSA. The Montgomery County production function for landfills will be applied to many suburban counties of the SMSA. This landfill is an adequately prepared sanitary landfill, while many private landfills are no more than dumps. Applying Montgomery County costs will over-estimate landfilling costs.

Thus disposal costs in the Philadelphia SMSA err in the direction of being (a bit) too large.

Summary

Information on waste disposal costs has been developed by the RSRI in a form suitable for input-output analysis. The information is based on actual accounting records of municipalities in the Philadelphia SMSA. Separate production functions were

estimated for various waste disposal processes including collection, transportation, landfill, and incineration. Waste disposal costs per ton of solid waste are summarized in Table 13.

TABLE 13

SUMMARY OF PRODUCTION FUNCTIONS FOR SOLID WASTE DISPOSAL ACTIVITIES,
PHILADELPHIA SMSA, FY 1972 (\$/TON)

SIC	COLLECTION	TRANSPORT	INCINERATION	LANDFILL	TRANSFER STATION
1511	.027	.013	.914	1.330	.440
2328	.063	.031			
2711	.003	.002			
2851			.157		
2911	.172	.085	.060	.010	.020
2992	.043	.021			
3011			.157	.100	.110
3079	.160	.079			
3429			.157	.100	.120
3461	.073	.036			
4811	.006	.003	.009		
4911			.145		
4941			.380		
6301	.289	.142			
6590				1.280	
7300			.388	.220	.490
7304	.146	.072			
7310	.015	.007			
7500	1.012	.499			
9888	9.665	4.760	3.033	.510	1.240
9892	.755	.372	1.036	.440	.360
9893	1.190	.586	.485	.090	.180
Total					
Cost/Ton	13.618	6.708	6.921	4.080	2.960

Bibliography

- City of Philadelphia. "Sanitation Cost and Production Reports for Fiscal Year 1972." Accounting Section, Department of Streets, Sanitation Division, 1972.
- Delaware County. "Annual Report. Performance and Cost of the Delaware County Disposal Department." Media, Pennsylvania, January 18, 1973.
- Kontuly, T. "Solid Waste Generation Coefficients: Non Manufacturing Sectors," unpublished memo, Regional Science Research Institute, March 1974.
- Montgomery County. "Solid Waste Fund 1973 Budget. Solid Waste Management System." Norristown, Pennsylvania, 1973.
- Steiker, G. "Solid Waste Coefficients" Manufacturing Sectors," Regional Science Research Institute Discussion Paper Series: No. 61, December 1973.
- Steiker, G. "A Framework for Evaluating the Economic Effects of Regional Solid Waste Systems," Regional Science Research Institute Discussion Paper Series, forthcoming 1974.
- Township of Upper Darby. "1972 Budget of the Ash, Rubbish and Garbage Department." Upper Darby, Pennsylvania, 1972.
- Township of Haverford. "1972 Budget of the Garbage Department." Haverford, Pennsylvania, 1972.

VI. PERCEPTIONS OF LANDFILL OPERATIONS HELD BY NEARBY RESIDENTS *

Introduction

One of the most difficult aspects of solid waste management is to obtain disposal sites. Neighborhood opposition to any proposed site is almost a certainty. As a result, sites are usually sought which are as far from settlements as possible. Locations along township boundaries are also sought since half of the neighbors to such locations (that is, the residents of the other town) have no voice in the decision.

Locations far from the settlements which generate the solid waste require hauling over excessive distances, and therefore may prove uneconomic, even when the relatively low land price of an inaccessible location is considered. Locations along a municipal boundary tend to be inequitable since they inflict undesirable environmental effects on neighbors who have no political recourse.

It is important, then, to gather and evaluate empirical data on the perceptions and attitudes which residents have concerning nearby solid waste disposal sites. Such data should help pinpoint the nature of the objections and may indicate specific aspects of design and operation which have a particularly critical effect on attitudes.

This study is concerned with the attitudes of residents to nearby sanitary landfill sites. Incinerator sites are not considered.

*Chapter VI written by Robert E. Coughlin, Harriet Newburger, and Carry Seigner.

Choice of Sanitary Landfills to be Studied

The study was carried out in the Pennsylvania portion of the Philadelphia metropolitan area.¹ A list of 48 landfill sites currently operating in this area was obtained from state and local officials.

In choosing the sanitary landfills for survey purposes, certain criteria had to be met. The first was that there had to be a sufficient number of houses close to the site to yield a sample of at least 30 respondents. Second, the landfill had to be isolated from influences such as incinerators or industries which might overshadow residents' attitudes towards the landfill. Third, the landfill had to meet minimum operating standards: it could not be a dump. Finally, the landfill had to be still in operation.

The 48 landfill sites were classified roughly according to size (small, medium, large), quality of operation (low, medium, high), and intensity of use (low, medium, high), as shown in Table 1. The three criteria mentioned above were then applied to each landfill: only 10 of the 48 sites were found acceptable for survey. Each landfill was visited before being accepted or rejected. Most of the rejected sites were either landfills not operated at

¹Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties.

Table 1

LANDFILLS OF SOUTHEASTERN PENNSYLVANIA CLASSIFIED BY
INTENSITY OF USE, ACREAGE, AND QUALITY OF OPERATION

INTENSITY OF USE	SIZE	Quality of Operation		
		HIGH QUALITY	MEDIUM QUALITY	LOW QUALITY
HIGH INTENSITY over 750 cu. yd./day over 30 trucks	LARGE (over 50 acres)	*Pottstown Disposal Service, Rimoharty, Mont. Co. (SR) S. E. Chester Refuse Auth. Ch. Co. (SR) - H	Knickacker, Ch. Co. (R) Moyer's Landfill, Mont. (R)	*Clearview Land Development Co., Del. Co. (SR) Fuleroft, Del. Co. (SR) - I
	MEDIUM (11-50 acres)	Warner, Bucks (NR) - H	Springfield Twp., Del. Co. (R) - H Schlavo, Phila. (SR) - I *St. Michael the Archangel, Bucks Co. (SR)	O'Hara Landfill, Mont. Co. (R) - X *Joseph Staszewski's Land- fill, Ch. Co. (SR)
	SMALL (10 acres or less)		Delaware Co., Marple Twp. (R) - I	Delaware Co., Chester Twp. (R) - I
MEDIUM INTENSITY 250-750 cu. yd./day 10-30 trucks	LARGE		Coatesville, Ch. Co. (NR) - H *Rhoads Landfill, Mont. Co. (SR)	
	MEDIUM	N.W. Incinerator, Phila. Co. (SR) - I	*H. Sweeney & Son, Del. Co. (SR) G. F. Mayer, Del. Co. (SR) - H	Dumino Salvage Co. (Sebo) Phila., (SR) - I Front & Pattison, Phila. (NR) - H Ft. Mifflin, Phila. (NR) Holmesburg Prison, Phila. (NR) - H
	SMALL		Montgomery Co. Quarry Site (NR) - H Pasquale's Quarry, Mont. Co. (R) - I	
LOW INTENSITY under 250 cu. yd./day less than 10 trucks	LARGE		South Coatesville, Ch. Co. (SR) - H	Salford Twp., Mont. Co. (R) - H
	MEDIUM	Francis Cloud, Ch. Co. (NR) - H Hooper's Landfill, Ch. Co. (SR) - H	Spring City, Ch. Co. (R) - I Savoy, Del. Co. (R) - X Whitemarsh Twp., Mont. Co. (R) - X Ambler Quarry, Inc., Mont. Co. (R) - H Upper Providence, Mont. Co. (SR) - H	Watson Johnson, Bucks Co. (SR) - H Chapman Johnson, Bucks Co. (SR) - H Pottstown Boro, Mont. Co. (R) - X Upper Providence, Del. Co. (SR) - H
	SMALL	*Parkesburg, Ch. Co. (NR) Londonderry, Ch. Co. (NR) - H	Barkman's Landfill, Ch. Co. (NR) - H W. Fallowfield, Ch. Co. (SR) - H Springfield Twp., Mont. Co. (SR) - X *Haverford Twp., Del. Co. (R) Lower Merion, Mont. Co. (Incinerator) (SR) - I Bartram Incinerator, Phila. Co. (SR) - I	Ferry Phillips, Ch. Co. (NR) - H Upper Dublin Twp. Mont. Co. (SR) - X

Density of Population

(R) = considerable residential development in vicinity
(SR) = some residential development in vicinity
(NR) = no residential development in vicinity

Reasons for rejection

X = closed
H = not near enough homes
I = near incinerator or industry

*Underlined landfills were chosen for study

the standards of a sanitary landfill (7 sites), not near a sufficient number of houses (18), or too close to incinerators and/or industry. Of the 10 "acceptable" sites, one was rejected because an intense political controversy concerning it was raging. A second was rejected because it was very similar to another acceptable landfill. The resulting 8 landfills formed the final sample for the household survey. These 8 landfills provide a wide spectrum of variation from very small to very large, and from urban to rural in location. The landfills chosen for survey are listed in Table 2 and their major characteristics noted.

Specific Operating Characteristics of Landfills

Truly objective data on the operating characteristics of a landfill are difficult to obtain. Even the number of tons of refuse dumped in the landfill on a given day--or peak hour-- is information not normally collected by the landfill operators. Accurate determination of such things as number of rodents, the amount of dust, the intensity of smells generated would require very careful and expensive measuring procedures. Because of the limited budget available for the research, it was decided to rely on ratings by experienced and expert personnel. State inspectors were turned to for these ratings.

Table 2
LANDFILL AND NEIGHBORHOOD CHARACTERISTICS

<u>Name of Landfill</u>	<u>Location</u>	<u>Landfill Characteristics</u>		
		<u>Nearby Density of Population</u>	<u>Intensity of Use</u>	<u>Size</u> <u>Quality</u>
Clearview	Darby Township Delaware County	very dense	high	large low
Rinehart	West Pottsgrove Township., Mont- gomery County	medium density	high	large high
Rhoads	Douglas Townshp. Montgomery Co.	medium density	medium/high	large medium/low
Blosenski	West Caln Townshp. Chester County	sparse	high	medium low
St. Michael	Levittown Bucks County	dense	high	medium medium
Sweeny	Middletown Town. Delaware County	dense	medium	medium medium
Parkesburg	Parkesburg Chester County	sparse	low	small high
Haverford	Haverford Townshp. Delaware County	dense	low	small medium

A state inspector visits each landfill at least once every two weeks and makes out an inspection report. Two such reports were obtained for each of the eight sites, one for an inspection in the summer of 1971 and one for an inspection in July or August 1972. These inspection reports indicate the specific areas of compliance and noncompliance at the landfill, such as correct compacting and covering the waste material, adequate equipment and safety measures, control of leachate, etc. They also indicate types and amounts of waste taken into each landfill. In addition to studying these inspection records we interviewed each inspector, asking for the following information: 1) the date the site was first opened and the previous use of the land, 2) the date the site will close and the future use of the land, and 3) a rating of specific problems at the disposal site, following the categories of our household survey, which will be described below.

From field observation and various maps and records, it was possible to estimate the number of acres owned and presently being used for the landfill, the number of small, medium, and large trucks using the landfill each day, the visibility and relative elevation of the landfill, soil type at the landfill, and cover material used. A brief set of notes on the history and circumstances surrounding each landfill was also compiled. The resulting

Table 3
SITE CHARACTERISTICS¹

	Blosenski	Clearview	St. Michaels	Rhoads	Haverford	Sweeney	Parkesburg	Rinerhart
<u>Quality of Operation (summer of 1971 & 1972)</u>								
A. Size of working face confined to area which can be covered easily; dust controlled at site; blowing litter controlled	2	2	1	1	1		1	
B. Layers of waste and cover of acceptable depth	4	2	2	3	2	1	1	
C. Leachate treated properly			1	1				1
<u>Quality of Operation (summer of 1972 only)</u>								
A1 same as A		2	1	1				
B1 same as B	3	2	1		1	1	1	
C1 same as C			1	1				
<u>Problems</u>								
D. Dust, smells, & paper blowing out of site	4	2	2	1				
E. Insects and rodents	1	2				1		
F. Pollution of surface & ground water		1	1	2	1	1		
G. Other	3		1		1	1	1	
<u>Size and Ownership</u>								
H. Area owned (ac.)	12	57	30	60	4	3.5	3.9	83
I. Area normally worked on in one day (ac.)	12	50	1	4.5	3	3.5	3.9	3.5
J. Trucks per day (no.)	37	125	40	21	6	30	6	30
K. Large trucks per day (no.)	37	88	40	7	0	0	0	30
S. Operation public = 1; private = 0	0	0	0	0	1	0	1	0
T. Years operating (no.)	1.5	20	10	35	14	15	35	20

¹Items A - G measured in deficiency points, derived from State Inspector's reports; other items in units stated, data gathered from direct observations, interview of operators, and interview of State inspectors.

data are listed in Appendix A and in the notes presented as Appendix E. Several characteristics were chosen as most representative and were used in subsequent analysis. These are listed in Table 3.

Household Interviews

Interviews were conducted with a sample of residents living near each of the eight landfills. The purpose of the interviews was to determine the extent of a resident's knowledge of, and the attitudes held toward, the nearby landfill. In order to interpret these data, information was also collected on personal (socio-economic) characteristics and on the location of the resident's house in relation to the landfill site. For this purpose, a questionnaire was designed and is included in Appendix F.

Houses were picked for interviewing on a random basis, depending upon the density of the houses surrounding the landfill. For example, at Clearview landfill every tenth house was chosen, while at Blosenski's landfill every household was interviewed. Interviewing was done in person, with two interviewers collecting the bulk of the data. The study provided for at least three callbacks (sometimes more) at each household in an attempt to reach those unavailable upon initial contact. In cases of refusals to

answer, the house next door was interviewed. If the respondent had no idea that there was a landfill in his neighborhood, the questionnaire was considered completed after asking how long the respondent had lived there. Interviewing was begun at houses closest to the site and radiated outward to a point where most of the respondents either did not know the landfill existed, or felt that it had no effect on their neighborhood.

Table 4
NUMBER OF RESPONDENTS INTERVIEWED

<u>Landfill</u>	<u>Total Number of Respondents</u>	<u>Number Who Knew about Landfill</u>
Clearview	236	191
Rinehart	89	77
Sweeny	99	80
Rhoads	107	98
Blosenski	88	77
St. Michael	120	111
Parkesburg	32	27
Haverford	73	42
	<u>844</u>	<u>703</u>

A total of 844 interviews were completed at the eight sites. They were conducted during the months of June, July, and August. 1972.

Knowledge of Landfill

Single tabulations of answers to questions concerning knowledge of the landfill's existence, the date operation began, previous and future area of the site, how the respondent acquired information about the site, and the type of operation (public/private, local/multi township) are given in Appendix B.

Existence of Landfill

The percent of those interviewed who knew of the existence of the landfill without being prompted varied from 51.7% around the Haverford landfill to 93.3 % around the Rinehart landfill. The median for the eight sites is estimated to be 82.6% (see Table 5).

In a few cases it was necessary to go as much as two miles from the landfill to reach the point where most of the residents did not know the landfill existed or felt it had no effect on their neighborhood. Residents who lived as much as five miles from Blosenski's on the disposal truck route felt they were affected by the landfill. At Parkesburg, almost everyone in the town knew of the landfill's existence, since it was the disposal site of all the household trash of the town and was owned by the

town, but it bothered almost no one. At Haverford, many people living a few hundred feet from the landfill had no idea it existed because the site is so small and so well hidden. Distance, thus, did not have a predictable effect on knowledge of landfill. This can be seen in the answers to question 1, "Can you tell me where the nearest trash disposal site is located?" The answer to this question is tabulated by distance of residence from landfill site.¹

Past and Future Use of Landfill Site

Moderate proportions (median site:² 47.1%; range: 20-58%) of respondents who were aware of the existence of a nearby landfill believed that they knew the previous use of the landfill site. Generally smaller proportions (median site: 19%; range: 0-56%) believed they knew when the landfill was opened. Still smaller proportions (median: 2.5%; range: 0-10%) believed they knew when the landfill would be closed. Although the respondents were quite uncertain about when the landfill would be closed, they were somewhat more confident that they knew what the future use

¹ Note that in addition to those responding positively to question 1, respondents able to identify the site after probing of question 2 are also classified as knowing about landfill in Table 5 and both constitute the basic sample for the remaining questions.

² Taking the percentage for each of the eight sites as an observation, the percent for the median site is the value halfway between the percentages for fourth and fifth sites when ranked in order of percentage.

Table 5
PERCENT WHO KNEW SITE WAS THERE (ANSWERS TO Q.1)

	<u>< 500'</u>	<u>500-1000'</u>	<u>1000-1500'</u>	<u>1500-2500'</u>	<u>2500-3500'</u>	<u>3500+</u>	<u>Total</u>
Blosenski	100 (6)	100 (13)	100 (7)	100 (15)	87.5 (8)	70.3 (27)	88.1 (76)
Clearview	100 (7)	90 (30)	84.6 (25)	69.7 (88)	63.8 (34)	0 (2)	77.2 (180)
St. Michaels	66.7 (12)	61.7 (34)	73.3 (30)	57.5 (32)	100 (1)	-	64.5 (109)
Rhoads	----	100 (9)	100 (34)	86.5 (51)	100 (2)	-	92.7 (96)
Haverford	66.6 (18)	52.1 (23)	0 (1)	-	-	-	57.1 (42)
Sweeny	78.3 (36)	71.4 (28)	62.5 (8)	71.4 (7)	-	-	74.6 (79)
Parkesburg	100 (1)	88.8 (9)	100 (3)	100 (5)	100 (3)	75 (4)	92.0 (25)
Rinehart	100 (6)	88.8 (9)	100 (5)	100 (23)	87.5 (8)	87.5 (24)	93.3 (75)

Note: Upper numbers are percents of those in the group who knew of site. Lower numbers in parentheses, are total number of respondents in group.

of the site would be. A median of 11.5 percent at a given site (range: 0-49%) said they knew what the future use would be.

For most sites, there was substantial agreement on what the future use would be among those respondents who stated a future use. However, respondents near Haverford were equally divided on whether the landfill site would be used for industry, for a park, or for a school or hospital. At Parkesburg, opinion was divided between an athletic field and "a school, hospital, or other." At Clearview, opinion was divided between a park and housing.

Perceptions, however, do not necessarily correspond with objective fact. Perceptions of past events (of when the landfill opened or what the previous use of the land was) may be checked fairly easily with objective information on past events. However, perceptions of future events cannot be checked. Unless some sort of binding agreement has been reached, the future use of a landfill site is particularly uncertain. Owners of most private landfills look on the sites as real estate which should be put to the most profitable use. Therefore, as the landfill approaches capacity, they desire to keep their options open and to seek the highest bidder for the land.

Residents' perceptions of future use, in such a situation, cannot be based on objective reality. As a result, perceptions may serve either to lull the residents into a sense of security about the future use, or to alarm the residents unnecessarily. For example, near Clearview 18% of the respondents (median for 8 landfills was 11.5%) said they knew what the future use would be. Of these 69% said it would be housing, 27% said it would be a park, and 2% said it would be a school, hospital, or other use. The owner of the site has been quoted as saying that he wanted the site to be used as a part of the Bicentennial Celebration in 1976 and had suggested his solid waste mountain would be a good site for a restaurant. These illusions were shattered about four months after our household survey: it was announced that a portion of the site would become an asphalt plant.

Generally, respondents were quite accurate in their perceptions of whether the landfill was operating when they moved into the neighborhood. Of the residents at the median site, 78.5% were correct in their present judgment of whether or not the site was operating when they moved in (the range was from 61 to 92%). Somewhat fewer (50% at the median site; range: 22 to 88%) were correct in their perception of whether they knew about it at the time. Percent of respondents having correct present and past per-

ceptions of when the landfill began operation are given in Table 6. Correctness of perception appears to bear very little relationship to distance from residence to landfill.

Sources of Information and Reasons Why Landfill Was Located in Neighborhood

The most common sources of information about the landfill site are neighbors (median site: 38.5%) or newspapers (median site: 32%). Relatively few get information from community organizations (median: 7.5%) or from public officials (median: 6%). A moderate proportion have gained first hand information by visiting the landfill (median site: 29.5%). The majority of residents, however, have not visited their nearby landfill. A sizeable proportion of these responded, "Why would I even want to go there."

Relatively small proportions of respondents ventured guesses as to why the landfill was put into their neighborhood (median site: 31%, range: 22-51%). Most of those who did venture a reason cited functional reasons, such as the land was owned by the operator or, less frequently, that vacant land was available with few close neighbors. The researchers had anticipated that many residents would be so upset by the fact that those in authority had allowed a landfill in their area, that they would have responded

Table 6

PERCEPTIONS OF WHETHER SITE WAS OPERATING WHEN
RESPONDENT MOVED INTO NEIGHBORHOOD (percent of respondents)

	<u>Correct Present Perception (1)</u>	<u>Correct Past Perception (2)</u>
Blosenski	61 (76)	22 (73)
Clearview	77 (171)	40 (170)
St. Michael	88 (108)	30 (103)
Rhoades	78 (93)	62 (93)
Haverford	66 (35)	60 (35)
Sweeny	79 (66)	37 (65)
Parkesburg	92 (25)	88 (24)
Reinhart	84 (69)	62 (68)

1. Q. 10 and date of first operation.
2. Q. 11 and date of first operation.

Note: Upper number is percent of respondents; lower number, in parentheses, is total number of respondents in group.

that it was placed in the neighborhood because the neighborhood had no power to stop it. Very few responded that way. It may be that deeper probing is necessary to elicit such answers.

Attitude Toward Landfills

Simple tabulations of answers to questions concerning attitudes toward landfills can be found in Appendix C. These questions include the effect the landfill has on the neighborhood, and on the value of the individual's property; its effect on past and present desire to move into the neighborhood; and specific problems perceived.

Effect on Neighborhood

The researchers had assumed that the large majority of residents would feel the deleterious effects of the landfill quite strongly. However, around the typical landfill (median size), only 50.5% of respondents felt that the landfill had an important effect on the neighborhood. The range was from 22% to 79% for the eight landfills. For the worst landfills, this attitude drops off fairly consistently with distance to residence; but for the others there is no discernible trend with distance (Table 7).

The respondents indicate that the presence of the landfills had little effect on their decisions to move into the neighborhood. For the typical landfill, 95.5% of the respondents who had known about the landfill said that knowledge of it had no effect

on their decision. (The range was from 82 to 100%). This subset of people was "self-selected" in the sense that it contains relatively few of those for whom the landfill would be a major problem. Presumably, such people are not likely to have moved into the neighborhood if they were aware of the landfill.

Residents who moved in before the landfill operation began or who were unaware of the landfill's existence are likely to be more typical of the population at large. Even of these, however, a large majority (75.5% for the median landfill; range from 53% to 97%) felt that knowledge of the landfill would have made no difference (question 13). A significant minority, however, reacted strongly against the presence of the landfill. At the median landfill, 9.5% said they "definitely would not" and 15% said they "probably would not" have moved in, had they known of the landfill's existence.

The responses were similar when the respondents were asked the question, "Considering the site as it is now, would you move in?" These responses, too, showed no strong trend with distance between landfill and residence.

In general, these responses are consistent with the respondents' estimates of effects on property value. At the median site 87% said the landfill had no effect on property value (range: 59% to 94%).

Table 7
PERCENT OF RESPONDENTS WHO STATED THAT THE LANDFILL
HAS AN IMPORTANT EFFECT ON NEIGHBORHOOD*

	< 500'	500-1000'	1000-1500'	1500-2500'	2500-3000'	3500 +	Total
Blosenski	83.3 (6)	100 (12)	100 (6)	68.7 (16)	50.0 (8)	73.0 (26)	77.0 (74)
Clearview	100 (7)	96.7 (30)	92.3 (26)	76.1 (84)	60.0 (35)	50.0 (2)	79.3 (184)
St. Michaels	91.6 (12)	63.6 (33)	53.5 (28)	45.1 (31)	0 (1)	----	58.0 (105)
Rhoad's	----	33.3 (9)	26.4 (34)	28.0 (50)	100 (2)	----	29.4 (95)
Haverford	47.0 (17)	59.0 (22)	0 (1)	----	----	----	52.5 (40)
Sweeny	40.0 (35)	59.2 (37)	37.5 (8)	28.5 (7)	----	----	45.4 (77)
Parkesburg	----	22.2 (9)	25.0 (4)	33.3 (6)	66.7 (3)	0 (4)	27.0 (26)
Rinehart	16.7 (6)	11.1 (9)	40.0 (5)	21.7 (23)	30.0 (10)	20.8 (24)	22.0 (77)

*Answers to Question 3a.

Note: Upper numbers refer to percents of respondents in distance group. Lower numbers, in parentheses, refer to total number of respondents in distance group.

On average, 9.5% said the presence of the landfill made their property worth a little less. Although few persons said it made their property worth much less, responses varied greatly from landfill to landfill. At Clearview 16% and at Blosenski 8% said the presence of the landfill made their property worth much less; at two sites only 1% and at four sites 0% reported such a strong adverse effect. Responses indicating "much less" and "a little less" are tabulated by distance in Table 8. Again a trend with distance is evident only for the most objectionable landfills.

The attitudes of "old settlers," those who lived in the neighborhood before the landfill began operation, differ from the attitudes of those who moved in after operation had begun. The poorly-run landfills are resented more by old settlers, who state more frequently that they would definitely not or probably not move in, considering the site as it is now. This is the expected relationship. However, the better-run landfills appeared to be more resented by newcomers. At four of the better-run landfills, none of the old timers stated that they would definitely not or probably not move in if they had knowledge of the landfill, whereas between 4 and 9 percent of newcomers stated that the landfill would dissuade them from moving in (Table 9). This may suggest that a landfill may not be considered a problem by old settlers who know

all the facts and circumstances. However, a minority of newcomers, who may not be well acquainted with the details of history or present operation, may be perceiving and reacting to the landfill in a stereotyped manner. The same pattern may be seen in the perceived effect on property values, and on the neighborhood (Table 9).

The generally high scores achieved by the Rhoads and Haverford sites suggest, in addition, that the acceptance of a landfill is more likely if it is managed well by local government or by a local person who is known and respected.

Specific Problems Perceived

The respondents were asked to rate the seriousness of a number of specific types of problems on a 3-point scale: not important, bad, very bad (question 26). They were then asked to identify from these, the three worst problems (question 27). Scores from these two questions were added together to derive a scale with six possible points, points 1-3 being important, bad, very bad, and points 4-6 indicating successively worse evaluations. Scores for each potential problem at each site are plotted in Figure 1. They indicate that only a few potential problems were rated very bad or worse at any sites (i.e., a rating of 3 or more). Smells

TABLE 8

PERCENTS OF RESIDENTS AT EACH DISTANCE WHO STATED THAT OPERATION
OF DISPOSAL SITE MADE THEIR PROPERTY WORTH MUCH OR A LITTLE LESS¹

	<u><500'</u>	<u>500-1000'</u>	<u>1000-1500'</u>	<u>1500-2500'</u>	<u>2500-3500'</u>	<u>3500'+</u>	<u>Total</u>
Blosenski	83.3 (6)	36.3 (11)	50.0 (6)	50.0 (14)	0 (7)	18.2 (22)	34.8 (66)
Clearview	83.3 (6)	74.0 (27)	47.8 (23)	23.8 (63)	20.8 (24)	0 (1)	38.8 (144)
St. Michaels	18.1 (11)	6.6 (30)	6.8 (29)	7.1 (28)	0 (1)	-	8.0 (99)
Rhoads	-	0 (8)	6.0 (33)	2.3 (42)	0 (2)	-	3.5 (85)
Haverford	0 (17)	18.1 (22)	0 (1)	-	-	-	10.0 (40)
Sweeny	18.7 (32)	11.5 (26)	16.7 (6)	0 (7)	-	-	14.0 (71)
Parkesburg	0 (1)	0 (6)	0 (4)	0 (4)	33.3 (3)	0 (4)	4.5 (22)
Rinehart	16.7 (6)	16.7 (6)	0 (4)	0 (21)	0 (8)	10.0 (22)	5.9 (67)

*Answers to Question 22.

Note: Upper numbers refer to percents of respondents in distance group. Lower numbers, in parentheses, refer to total number of respondents in distance group.

were so rated at three sites; pollute water, paper from site, and noise were not rated very bad or worse at any site, and the remaining potential problems were rated very bad or worse at only one site each.

At any one site typically between 0 and 20% of the residents rated a problem as "very bad." However, most potential problems listed received a "very bad" rating by a substantially higher percentage of people around at least one landfill -- generally by the people around Blosenski or Clearview. Percent of respondents giving a "very bad" rating to each potential problem is charted in Figure 2. The grouping in the 0%-20% range is evident as are the outlying points in the 40% and over range.

The most serious problem would appear to be "smells." At each landfill at least 8% of the respondents considered smells to be "very bad:" at Clearview 72% gave smells a very bad rating, and over 40% gave "very bad" ratings at St. Michaels and Blosenski. The least serious problem appears to be that of operating noise.

Landfill problems tend to be experienced in certain directions from the landfill (e.g., downwind for smells, dust, smoke) or along specific streets (e.g., along major truck access roads). The general measure of distance would appear to be less appropriate

TABLE 9
GENERAL ATTITUDES OF "OLD SETTLERS" AND "NEWCOMERS"¹
(Percent giving following answers.)

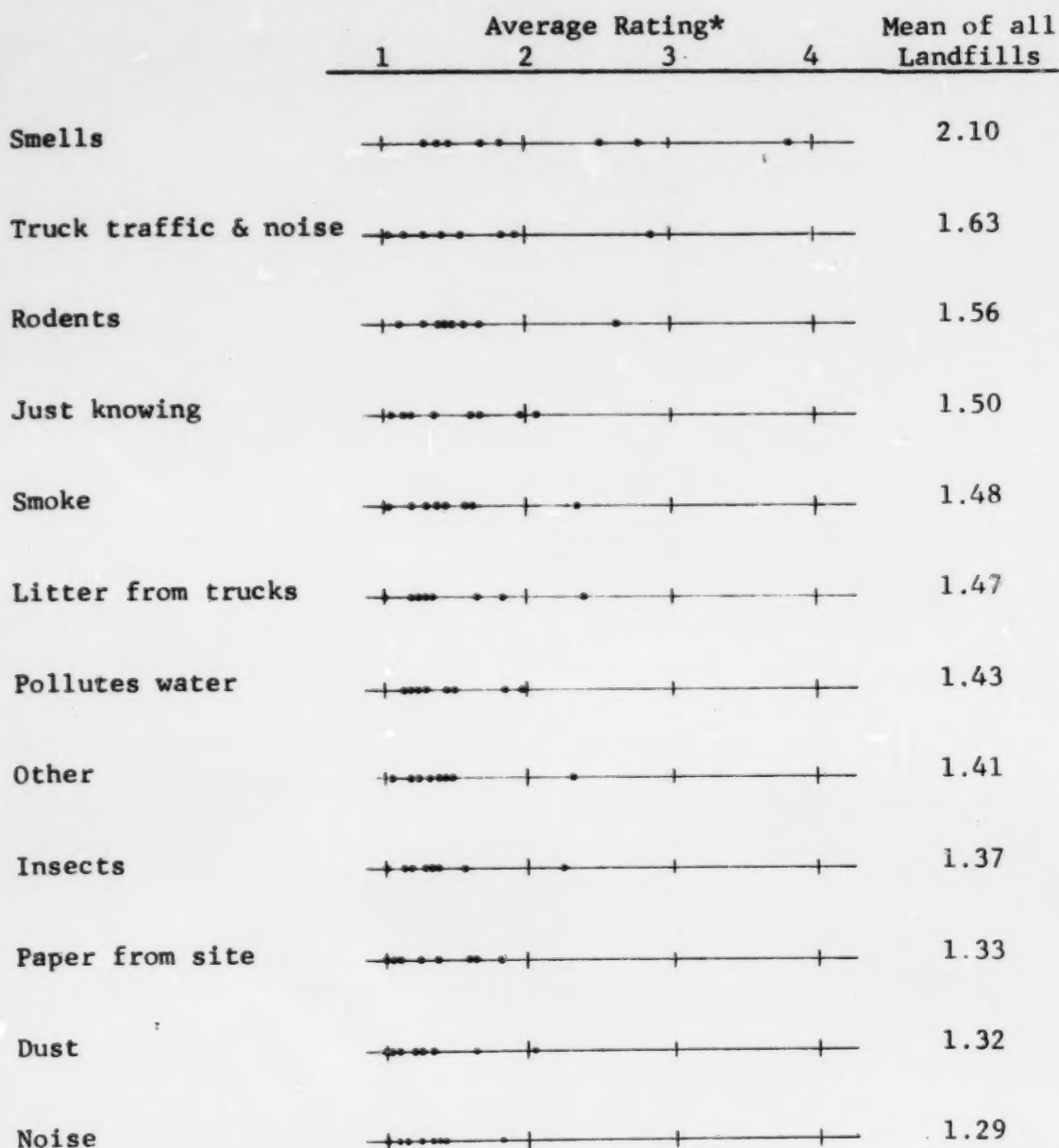
	Definitely or probably would not move in, considering site as it is now. (Question 14)			Property worth much or a little less since disposal began. (Question 22)		
	<u>Old Settlers</u>	<u>Newcomers</u>	<u>Total</u>	<u>Old Settlers</u>	<u>Newcomers</u>	<u>Total</u>
Blosenski	56.1 (41)	26.7 (30)	43.7 (71)	43.6 (39)	24. (23)	35.9 (64)
Clearview	54.8 (42)	40.2 (107)	44.3 (149)	37. (46)	43. (86)	41. (132)
St. Michaels	26.5 (49)	7.5 (53)	16.7 (102)	13. (46)	4.2 (48)	8.5 (94)
Rhoads	0 (7)	9.3 (86)	8.6 (93)	0 (6)	3.9 (77)	3.6 (83)
Haverford	0 (1)	9.4 (32)	9.1 (33)	0 (2)	10. (30)	9.4 (32)
Sweeny	33.4 (15)	20.4 (49)	23.4 (64)	20 (15)	15.6 (43)	16.7 (60)
Parkesburg	0 (1)	4.0 (25)	3.8 (26)	0 (1)	5. (20)	4.8 (21)
Rinehart	0 (13)	5.5 (55)	4.4 (68)	0 (12)	0.5 (47)	6.8 (59)

Disposal site has important effect
on neighborhood. (Question 2)

	<u>Old Settlers</u>	<u>Newcomers</u>	<u>Total</u>
Blosenski	78. (41)	75.9 (29)	77.1 (70)
Clearview	75 (48)	83.4 (120)	81. (168)
St. Michaels	70.1 (48)	49. (51)	60. (99)
Rhoads	57.1 (7)	29.1 (86)	31.1 (93)
Haverford	0 (1)	59.4 (32)	57.6 (33)
Sweeny	53.4 (15)	54.2 (48)	54. (63)
Parkesburg	1. (1)	25. (24)	28. (25)
Rinehart	14.3 (14)	25.4 (55)	23.2 (69)

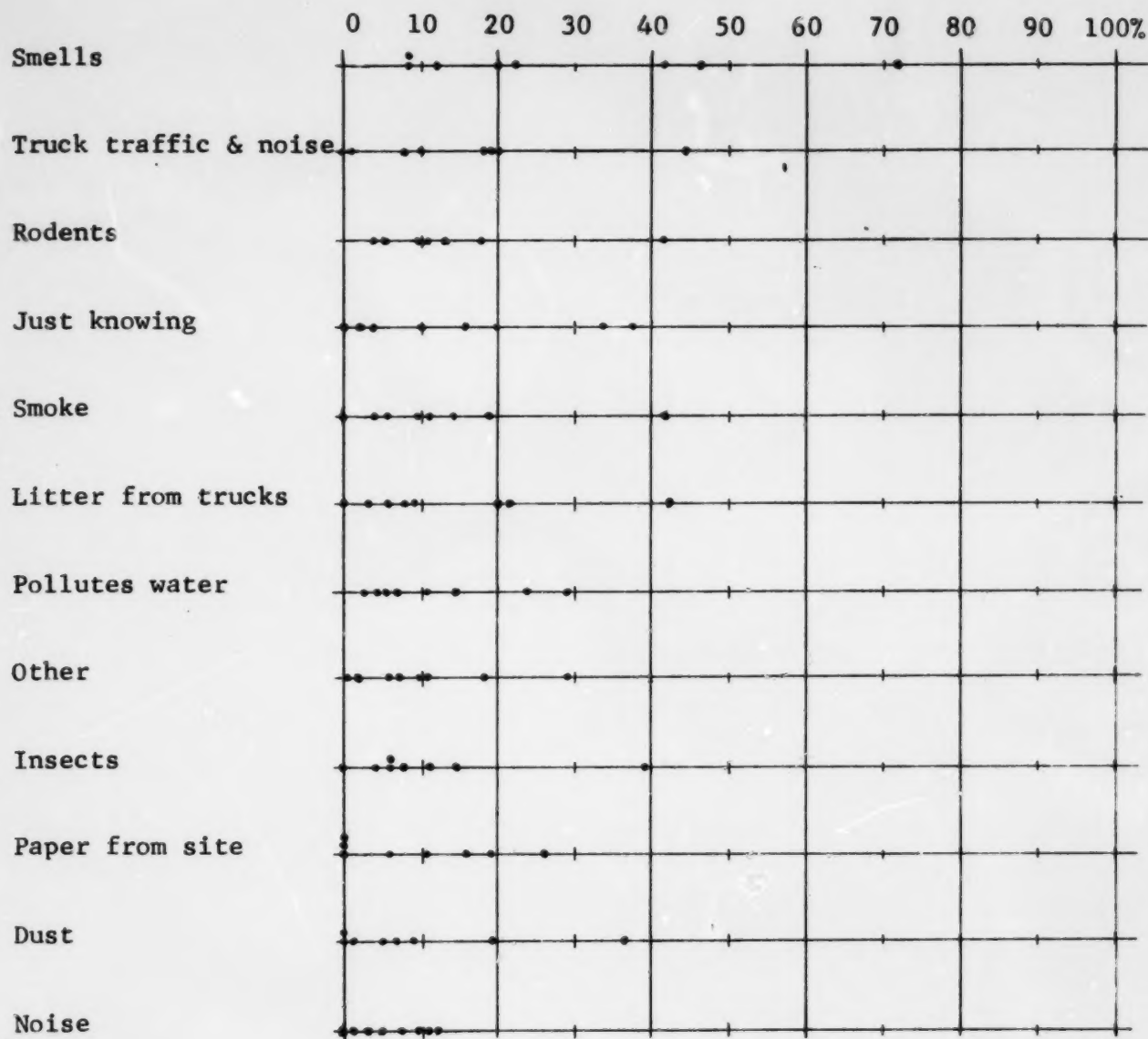
¹Old settlers defined as residents who moved into neighborhood before landfill operation began;
Newcomers defined as those who moved in after operation began (q.10).

Figure 1
AVERAGE RATING GIVEN TO PROBLEMS AT EACH LANDFILL



* Computed from answers to Questions 26 and 27. Basic score from Question 26 (1: not important; 2: fairly bad; 3: very bad) plus additional score for these problems which are most important (plus 3: the worst problem; plus 2: the second most important, plus 1: the third most important).

Figure 2
PERCENT OF RESPONDENTS AT EACH SITE RATING PROBLEM
AS "VERY BAD"



Source: Answers to Question 26.

here than in describing many other spatial phenomena. However, because of its very general nature it is of interest to see how distance-to-site is related to problem perception. Therefore, Table 10, which specifies three distance classes, is presented. Although there is a general decline with distance, many exceptions may be noted.

The perception of specific problems, like the perception of general attitudes discussed above, differs for old settlers and newcomers. Generally, in the more poorly-run landfills, both groups view a problem similarly. However, in the better-run landfills, the newcomers perceive the problems as being more severe than do the old settlers. This again suggests that a really noxious landfill is perceived for what it is, while an innocuous landfill is judged on the bad general reputation of landfills. (Table 11).

Specific problems of smells, rodents, litter, etc. are of interest in themselves. They are also of interest because they may suggest what physical or operational changes it would be most advantageous to carry out. For example, the survey results suggest that the improvement which would increase satisfaction of the neighbors most would be a reduction in smells.

Table 10

PERCENT OF RESPONDENTS AT EACH DISTANCE WHO GAVE HIGHEST (WORST)
RATINGS TO SPECIFIC PROBLEMS¹

	SMELLS				JUST KNOWING			
	0-500'	500'-1000'	1000'+	Total	0-500'	500'-1000'	1000'+	Total
Blosenski	50.0 (6)	38.4 (13)	31.0 (58)	33.7 (77)	83.3 (6)	15.3 (13)	32.8 (58)	33.7 (77)
Clearview	85.7 (7)	73.3 (30)	57.8 (147)	61.4 (184)	85.7 (7)	55.1 (29)	32.3 (148)	38.0 (184)
St. Michaels	66.7 (12)	38.2 (34)	23.0 (61)	32.7 (107)	41.6 (12)	11.7 (34)	18.3 (60)	18.8 (106)
Rhoads	0 (1)	11.1 (9)	11.4 (88)	11.2 (93)	-- (0)	0 (9)	3.4 (88)	3.0 (97)
Haverford	5.8 (17)	8.6 (23)	0 (1)	7.3 (41)	22.2 (18)	13.0 (23)	0 (0)	17.0 (41)
Sweeny	10.8 (37)	25.0 (28)	13.3 (15)	16.2 (80)	10.8 (37)	10.7 (28)	7.1 (14)	10.1 (79)
Parkesburg	0 (1)	22.2 (9)	0 (10)	10.0 (20)	0 (1)	0 (9)	0 (0)	0 (10)
Rinehart	16.6 (6)	11.1 (9)	0 --	13.3 (15)	0 (6)	11.1 (9)	3.2 (62)	3.8 (77)

	TRUCK TRAFFIC AND NOISE				RODENTS			
	0-500'	500'-1000'	1000'+	Total	0-500'	500'-1000'	1000'+	Total
Blosenski	16.7 (6)	7.7 (13)	41.4 (58)	33.8 (77)	0 (6)	23.1 (13)	3.5 (57)	6.6 (76)
Clearview	0 (7)	12.5 (56)	5 (122)	6.5 (185)	85.7 (7)	41.1 (56)	23.4 (124)	31.0 (187)
St. Michaels	7.7 (13)	2.9 (34)	0 (63)	1.8 (110)	30.8 (13)	17.6 (34)	6.3 (63)	12.7 (110)
Rhoads	0 (1)	44.4 (9)	10.6 (85)	13.7 (95)	-- (0)	0 (9)	6.8 (88)	6.2 (97)
Haverford	0 (18)	4.3 (23)	0 (1)	2.4 (42)	5.6 (18)	4.3 (23)	0 (1)	4.8 (42)
Sweeny	21.6 (37)	14.3 (28)	6.7 (15)	16.3 (80)	10.8 (37)	14.3 (28)	0 (15)	10.0 (80)
Parkesburg	0 (1)	0 (9)	0 (16)	0 (26)	0 (1)	11.1 (9)	11.8 (17)	11.2 (27)
Rinehart	16.7 (6)	0 (9)	5 (60)	5.3 (75)	0 (6)	0 (9)	4.8 (62)	3.9 (77)

¹Percent giving ratings of 4, 5, or 6 to a given problem. Ratings constructed as sum of answers to questions 26 and 27 as described in footnote to Figure 1.

Problems may be viewed in a general framework as well as under more specific categories. The eleven specific problems may contribute to more general effects, such as effects on health, property values, and appearance. The respondents respond decisively that they have been most affected by considerations of health (question 28).

Table 11
THE PERCEPTION OF SELECTED SPECIFIC PROBLEMS BY "OLD SETTLERS" AND NEWCOMERS¹
(Percent of each group who gave the highest (worst) rating to specific problems (i.e., giving a rating of 4, 5, or 6 to the combination of Questions 26 and 27).

	Smells			Just. Knowing		
	Old Settlers	Newcomers	Total	Old Settlers	Newcomers	Total
Blosenski	31.0 (42)	35.5 (31)	32.9 (73)	4.8 (42)	6.5 (31)	5.5 (73)
Clearview	66.0 (50)	62.0 (121)	63.2 (171)	6.0 (50)	5.8 (121)	5.8 (171)
St. Michaels	46.9 (49)	20.4 (54)	33.0 (103)	10.4 (48)	7.5 (53)	8.9 (101)
Rhoads	0 (7)	12.8 (86)	11.8 (93)	14.3 (7)	2.3 (86)	3.2 (93)
Haverford	0 (2)	9.4 (32)	8.8 (34)	0 (2)	16.7 (33)	14.3 (35)
Sweeny	13.0 (15)	21.6 (51)	20.0 (66)	0 (15)	5.9 (51)	4.5 (66)
Parkesburg	0 (1)	8.0 (25)	7.7 (26)	0 (1)	0 (25)	0 (26)
Rinehart	7.1 (14)	7.3 (59)	7.2 (69)	0 (14)	3.6 (55)	2.9 (69)

	Truck Traffic & Noise			Rodents		
	Old Settlers	Newcomers	Total	Old Settlers	Newcomers	Total
Blosenski	46.3 (41)	19.4 (31)	34.7 (72)	7.1 (42)	6.5 (31)	6.8 (73)
Clearview	8.0 (50)	7.4 (121)	7.6 (171)	30.0 (50)	32.2 (121)	31.6 (171)
St. Michaels	0 (49)	3.8 (53)	2.0 (102)	18.4 (49)	9.4 (53)	13.7 (102)
Rhoads	0 (6)	18.7 (86)	17.4 (92)	0 (7)	8.1 (86)	7.5 (93)
Haverford	0 (2)	3.0 (33)	2.9 (35)	0 (2)	6.1 (33)	5.7 (35)
Sweeny	20.0 (15)	17.6 (51)	18.1 (66)	13.3 (15)	11.8 (51)	12.1 (66)
Parkesburg	0 (1)	4.0 (25)	3.8 (26)	0 (1)	12.0 (25)	11.5 (26)
Rinehart	7.1 (14)	9.1 (55)	8.7 (69)	0 (14)	5.5 (55)	4.3 (69)

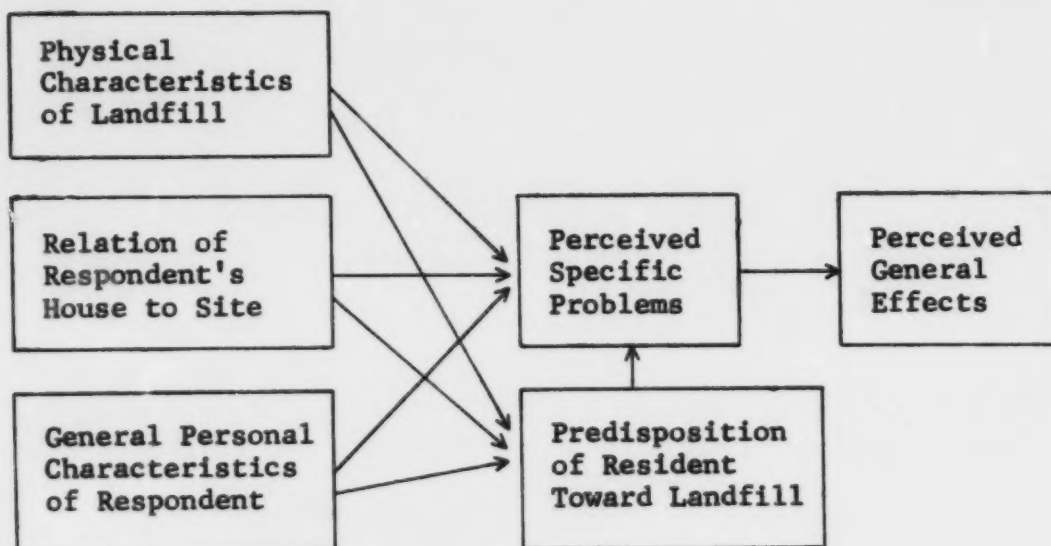
¹Old settlers are defined as those who stated that the disposal site was not operating when they moved in to the neighborhood; newcomers are those who stated that it was operating when they moved in.

Perception of Effects of Landfills

The existence of a sanitary landfill may affect a neighbor's attitude toward the quality of his neighborhood and the value of his own property. These perceived general effects provide a means of gauging the importance of the landfill to residents.

One can hypothesize that the general effects perceived by a resident are not determined simply by the characteristics of the landfill. They are also affected by such factors as the location of his house with respect to the landfill, resident's general social and economic characteristics, his particular predisposition towards the sanitary landfill, and the particular problems concerning it which he perceives. The relationship between these factors and the general effects perceived by the respondents is diagrammed in Figure 3. In general, the characteristics of site and respondent are conceptualized as determining the general effects which are perceived. The first multiple regression analysis to be described below treats the perceived general effects as dependent variables, and variables relating to all other boxes in Figure 3 as independent variables. The second regression analysis omits all variables relating to the intermediate factors: predisposition of respondent towards landfill and perceived specific problems.

Figure 3
HYPOTHETICAL RELATIONSHIPS AMONG FACTORS
AFFECTING PERCEPTION OF LANDFILL SITES



Three questions in the survey relating to perceived general effects (questions 3, 14, and 23) have been chosen for analysis.¹ These questions are identified as dependent variables in Table 12. Variables describing each of the other factors listed in Figure 3 have been specified from the objective data on the eight landfills and the survey data on residents living near them, and are listed as independent variables in Table 12.

¹ Question 28 is also relevant, but too few answered it to warrant extensive statistical analysis.

Table 12
VARIABLES ENTERED IN REGRESSION ANALYSIS¹

A. DEPENDENT VARIABLES

- 4. Perceived detrimental effect on neighborhood
 - greatly improves neighborhood = 1
 - slightly improves neighborhood = 2
 - has little effect = 3
 - slightly detrimental to neighborhood = 4
 - very detrimental to neighborhood = 5
- 43. Perceived positive effect of disposal site on property values
 - worth much less because of disposal = 1
 - worth a little less because of disposal = 2
 - disposal has had no effect on house value = 3
 - worth a little more because of disposal = 4
 - worth much more because of disposal = 5
- 34. Effect of present knowledge on desire to move into neighborhood
 - definitely not = 1
 - probably not = 2
 - wouldn't make any difference = 3
 - would be a little more likely to move in = 4
 - would have been much more likely to move in = 5

¹Numbers and letters used to designate variables were developed for coding purposes. They do not correspond to question numbers.

Table 12 - cont.
VARIABLES ENTERED IN REGRESSION ANALYSIS

B. INDEPENDENT VARIABLES

Measured Site Characteristics (one observation for each site)
Quality of Operation (Numbers of times found not-in-compliance
in State inspection)

- A. Size of working face not confined to area which can be covered and compacted easily; dust not controlled at site; blowing litter not controlled.
Observation for 1971 and 1972: No. of times not in compliance with standard.
- B. Layers of waste and cover not of acceptable depth.
Observations for 1971 and 1972: No. of times not in compliance with standard.
- C. Leachate not treated properly. Observations for 1971 and 1972: No. of times not in compliance with standard.

- A₁
- B₁ Same as A, B, and C except that observations for summer 1972 only.
- C₁

Problems (Inspector's ratings: not important = 1, fairly bad = 2, very bad = 3)

- D. Dust; smells; and paper blowing out of site
- E. Insects and rodents
- F. Pollution of surface and ground water
- G. Other problems

Size and Ownership

- H. Area owned
- I. Area normally worked on in day
- J. No. trucks per day
- K. No. large trucks per day
- S. Operated by public = 1, or private = 0 .

Table 12 - cont.

(For the remaining variables there is one observation per respondent)

Predisposition

27. Importance of physical attractiveness when moved in
most important = 5,...,least important = 1
- O. Correct present perception of whether site was operating
when moved in.
correct = 2 incorrect = 1
- P. Correct past perception of whether site was operating when
moved in
correct = 2 incorrect = 1
- Q. How knowledge of site would have affected decision to move in
definitely not moved in = 1,...,much more likely to move in = 5
39. Perception of whether trucks pass in front of house
do pass = 2 do not pass = 1
- R. Correct perception of whether trucks pass in front of house
correct = 2 incorrect = 1
66. Perception that operations have: improved = 1, gotten worse = 2

Important problems perceived (not important = 1, fairly bad = 2,
very bad = 3)

50. truck traffic and noise
51. litter dropped from trucks on neighborhood streets
52. paper blows out of disposal site
53. rodents
54. smells
55. smoke
56. insects
57. noise from site operation
58. just knowing it is there
59. pollutes ground water
60. dust
61. other

Table 12 - cont.

Personal Characteristics

- L Site actually operating when respondent moved in
yes = 2, no = 1
- 36 Lived near trash disposal site before
yes = 2, no = 1
- 38 Have visited this landfill site
yes = 2, no = 1
- 42 Rent house = 2, own house = 1
- M Have young (0-12 yrs. old) children
yes = 2, no = 1
- 73 Number of years of education of head of household
- 74 Yearly income of household

Location of Residence with Respect to Landfill

- N Can see site from house
yes = 2, no = 1
- 75 Located on trash truck route to dump
yes = 1, no = 0
- 76 Distance (straight-line) to site
- 37 Extent to which landfill site can be seen from house
cannot see site = 1
disposal operation itself = 5

Overall Regression Analysis

The results of the first set of stepwise regression analyses are given in Table 13. In each case, the regression results are from the step giving the highest R^2 for which all independent variables in the equation are significant at the 0.05 level (have t-statistics exceeding 1.96). In general, it may be said that moderate levels of statistical significance were found for each equation as a whole, and that a large number of statistically significant independent variables was identified.

The group of independent variables contributing least to statistical significance was that of "personal characteristics." This is not surprising, since research carried out both by the Regional Science Research Institute and other institutions has indicated that the typical socio-economic indicators tell little about environmental preferences. In fact, none of the traditional socio-economic measures proved statistically significant in the regression equations. The only personal characteristic which was significant in any equation was the very particular characteristic: "Site operating when respondent moved in."

Perceived overall effects were also only weakly related to measured site characteristics. Therefore, in order to be sure that the site characteristics would be present in each equation,

Table 13

FOUR EQUATIONS RESULTING FROM OVERALL REGRESSION ANALYSES

Independent Variables:	Dependent Variables:			
	Perceived Detrimental Effect on Neighborhood Equation 1 Al & B1 forced Coef. F-Stat.	Perceived Positive Effect on Property Value Equation 2 Al & B1 forced Coef. F-Stat.	Present knowledge would increase desire to move in now	
			Equation 3 D & E Forced Q Suppressed Coef. F-Stat.	Equation 4 Nothing forced Q Suppressed Coef. F-Stat.
<u>Measured Site Characteristics</u>				
A1 Size of working face not confined (summer 1972)	.083* 3.4227	-.037* 7.523		
B1 Layers not of adequate depth (summer 1972)	.192* 35.3208	-.039* 10.336		
Z Insect and Rodent Problem			-.1156* 12.96	-.1026 10.969
D Dust, smells and paper blowing out of site.			-.0460* 4.83	
<u>Predisposition Characteristics</u>				
F Correct past perception of whether operating	-.166 8.7656			.1961 14.185
Q Knowledge would have increased desire to move in		.193 46.609		
64 Operations gotten worse		-.286 30.063		
27 Importance of physical attractiveness of neighborhood				.0375 6.439
<u>Immediate Problems Perceived</u>				
30 Truck traffic and noise	.102 25.814			
32 Paper blows out	.130 21.329	-.090 28.061		
33 Rodents	.035 7.625			-.0691 17.084
34 Smells	.162 89.042		-.0088 35.28	-.0625 17.041
38 Just knowing its there	.234 71.425		-.1470 36.85	-.1176 24.799
39 Water Pollution	.083 11.156			
37 Noise from site		-.158 56.6495	-.1499 23.97	-.1177 16.022
31 Litter dropped from trucks				-.0544 7.304
35 Smoke				-.0391 6.600
<u>Personal Characteristics</u>				
L Site operating when respondent moved in				.1994 15.473
<u>Physical Relationship between site and respondent</u>				
76 Distance	-.0520 9.2147			
75 Respondent located on truck route				-.1960 12.696
Constant	2.5097	3.0701	3.4272	2.7953
R ²	.5556	.5329	.2903	.3726
Standard error of estimate	.6740	.4234	.6132	.5790
F	86.13	57.65	57.78	37.15
Degrees of Freedom	(10, 689)	(6, 693)	(5, 694)	(11, 688)

* Variable forced to be in regression. Other variables selected on statistical grounds in stepwise procedure, so as to maximize increase at each step.

a preliminary analysis was performed: the site characteristic variables yielding the best explanation were chosen, and these were forced into the equations. They appear in the final equations with only moderately strong explanatory power.

The really strong variables, in general, are those which relate directly to predisposition for perception and to specific things perceived. Thus the primary statistical explanation for overall attitude is found in the realm of perception rather than in that of personal characteristics, closeness to site or access roads, or physical characteristics of the site itself. This is somewhat disappointing, since it may simply indicate a consistency between specific perceptions and general perceptions. Even if a deeper validity may be assigned, the findings are of limited value for planning.

The planner may be able to change the operating characteristics of the landfill site, or design it and its access to minimize the relationship between the site and residents. He could also choose to locate the landfill in a neighborhood inhabited by people whose personal characteristics would lead one to expect that they would not be unduly disturbed by a nearby landfill. However, our analysis indicates that any of these actions may have only a limited effect on the reactions

of residents to the landfill. The strongest and most reliable effects come from the predisposition of the residents and the particular problems they perceive. It would seem difficult to predict these in advance, and therefore difficult to use them in planning to minimize the neighborhood effects of landfill sites.

Despite the difficulty of applying the regression results of Table 13 to planning, the results are of considerable interest in themselves. The first equation, which explains "the perceived detrimental effect on the neighborhood," indicates the importance of particular problems which are perceived. "Smells" is the strongest variable, as might be expected. ("Smells" also appear in the third and fourth equations in the Table). More surprising, is the appearance of "Just knowing it is there" as the second strongest variable. This variable, expressing a general awareness of the landfill, also appears in equation 4, where it is the strongest of all independent variables. Its appearance suggests that a landfill may have a psychological effect which transcends and possibly is somewhat independent of particular characteristics and perceptions.

The remaining variables appear in the first equation with the expected signs. Residents having a correct perception of whether or not the landfill was operating when they moved in now perceive the landfill as less detrimental than those who moved in

under a misconception. The more a person can see of a landfill, the more detrimental he considers it to be.

The second equation, which seeks to explain the "perceived positive effect on property values," has a somewhat lower level of significance and contains a smaller number of significant independent variables. However, all the variables which entered the equations are strongly significant and are of the expected sign. Explanation is provided entirely by variables in the "predisposition" and "immediate problems perceived" groups.

The third and fourth equations both have as the dependent variable "Present state of knowledge would increase desire to move in now." In both versions, the variable "knowledge would have increased desire to move in" has been suppressed since it is largely redundant with the dependent variable. In the first version two independent variables relating to measured site characteristics were forced into the regression. These are: insect and rodent problems and dust, smells and paper blowing out of the site, each as measured by state inspectors. The only other variables to enter the equation were those in the immediate-problems-perceived group.

In the second version no variable was forced, and the results were substantially stronger. One measured site

characteristic entered the equation, along with two predisposition characteristics, six perceived problems, one personal characteristics variable, and one variable describing the physical relationship between respondent's house and the site -- a total of 11 significant variables.

Regression Analysis of Selected Factors

A second regression analysis was performed in order to focus on the relations between characteristics of sites and residents on the one hand and perceived general effects, without identifying the intermediate conditions of predisposition and the intermediate specific problems perceived (Figure 3). Thus, an explanation of perceived general effects was sought in terms of measured site characteristics, personal characteristics of respondents, and physical relationships between landfill site and house. In this analysis no variables were forced into the equations.

Overall, the results of this analysis were of somewhat lower significance than those of the overall analysis reported above. However, for each of the three dependent variables, between 5 and 7 independent variables were found to be significant at the 0.05 level. All signs were in the expected direction. Most of the variables appearing at a significant level in this analysis are

Table 14

THREE EQUATIONS RESULTING FROM REGRESSION ANALYSIS WITH LIMITED SET OF INDEPENDENT VARIABLES

Independent Variables:	Dependent Variables		Perceived Positive Effect on Property Value		Present knowledge would increase desire to move in now	
	Perceived Detri- mental Effect on Neighborhood Equation 5	Coef. F-stat.	Coef. F-stat.	Equation 6	Coef. F-stat.	Equation 7
<u>Measured Site Characteristics</u>						
A1 Size of working face not confined (summer 1972)		.2089 13.70			-.1485	20.40
B1 Layers not of adequate depth		.5051 109.69				
H Area owned		.0037 4.16				
I Dust, smells, & paper blowing out of site				14.06		
E Insects and rodents				60.78		
J Number of trucks per day					.0042	34.83
<u>Personal Characteristics</u>						
L Site operating when moved in	-.2109 8.66				.2640	21.92
42 Rent house	-.2981 9.51				.2665	12.69
74 Yearly income of household	.0017 5.60					
<u>Physical Relationship between Landfill Site & House</u>						
37 Extent can see site	.3727 29.37			39.16	-.3194	37.41
75 Located on truck route				10.43	-.2153	13.15
76 Straight line distance from site				5.77		
Constant	3.035		3.30		2.78	
R ²	.3379			.1909		.2267
Standard Error of Estimate	.8215			.4660		.6405
F-ratio	44.08			32.75		33.86
Degrees of Freedom	(8, 691)			(5, 694)		(6, 693)

different from the variables which appeared in the first regression analysis (Table 14) .

Variables in the "measured site characteristics" group were among the most significant variables in all equations. However, "size of working face not confined" was the only variable to appear in two equations. "Layers not of adequate depth" was highly significant in the equation regarding perceived detrimental effect on neighborhood, and "insects and rodents" were highly significant in the equation regarding perceived effect on property value.

In the personal characteristics group the variables "site operating when moved in" and "rent house" were significant in both the first and third equations. Thus, perceived detrimental general effects are likely to be less for persons who moved in after the landfill began operation and who rent rather than own their houses.

The one variable which was significant in all three equations is the "extent to which the respondent can see the landfill site from his house."

General Conclusions

A questionnaire survey of the type conducted for this study yields a vast quantity of data. While the analysis reported above deals with what appears to be the most salient data, many other findings have not been selected for analysis. The basic tabulations, however, are presented as Appendix Tables B, C, and D.

In general, landfills are recognized as having a negative influence, but do not appear to be perceived as having extremely deleterious effects on neighborhoods or on individual property values, at least by the people who live there. Of course, no data are available on people who were deterred from moving into a neighborhood because of the existence of a landfill. However, the relatively mild reactions stated by people who lived in neighborhoods before landfill operations began suggest that not many prospective residents would avoid a neighborhood because of a landfill.

People who lived in a neighborhood before the landfill began operation are likely to resent the landfill more than newcomers. However, some of the better run landfills are resented more by new comers than by those who moved in before the landfill began operations. This suggests that the newcomers may be reacting

more to a general stereotyped notion of the nature of a landfill than to the actual operating characteristics and effects of the landfill. This general notion, that the reaction to a landfill may be somewhat divorced from its actual characteristics, is suggested by the large percentage who listed as a major problem "just the fact that it is there."

At any rate, physical characteristics of a landfill are only one of the factors which explain the general effects of a landfill which residents perceive. The general personal characteristics of a respondent and his specific predisposition towards landfills must also be considered. These factors, however, must generally be considered "given" for a particular neighborhood. They may be a minor consideration in locating a new landfill.

Officials responsible for waste management are more properly concerned with the physical problems associated with landfill operation. It would appear that the reduction of smells, and minimization of the size of the working face would, in general, result in the greatest increase in satisfaction of neighbors. At particular sites, of course, particular problems, such as rodents, flies, etc., may be extreme, and their elimination should be given high priority.

Finally, the planner would be ill-advised to think of the landfill site as having a well defined area of influence on a neighborhood. Few regularities with distance were found, though for the largest and worst run landfills some generalizations by distance were possible.

APPENDIX A
OPERATING CHARACTERISTICS AND PHYSICAL CHARACTERISTICS OF LANDFILLS

1. LANDFILL INSPECTION REPORTS

	Clear- view '71/'72	Rine- hart '71/'72	Sweeny '71/'72	Rhoads '71/'72	Blosen- ski '71/'72	St. Michael '71/'72	Parkes- burg '71/'72	Haver- ford '71/'72
(x = noncompliance)					y			
All-weather access roads to site							x	
Telephone or radio communications to site							x	
Adequate equipment for minimizing fire hazards					x		x	
Access limited to those times when an attendant is on duty				x		x	x	
Hours of operation prominently posted					x	x		
Maintenance of daily operational records					x		x	x
Operational plan followed at site	x	x		x	x	x	x	x
Provisions available to weigh or measure solid waste					x	x	x	x
Unloading areas clearly indicated and restricted to 30' of working face					x	x		
Size of the working face confined to an area which can be easily compacted and covered daily								x
Blowing litter controlled	x	x		x	x	x	x	
Solid waste spread and compacted in layers not exceeding 2'					x			x
Individual cells 8' thick or less								
Uniform layer of cover material, compacted to a minimum of 6", placed on all exposed solid waste at the end of each day	x			x		x	x	x

	Clear- view '71/'72	Rine- hart '71/'72	Sweeny '71/'72	Rhoads '71/'72	Blosen- ski '71/'72	St. Michael '71/'72	Parkes- burg '71/'72	Haver- ford '71/'72
Intermediate layer of cover material, at least one foot thick, placed on completed lifts where there will be another lift within one year	x		x	x	x			x
Final layer of cover material, compacted to at least 2', placed over the entire surface of final lift.								
Suitable standby equipment available			x		x			
Disposal of sewage solids, liquids and hazardous waste handled with the approval of the Dept. of Environ. Resources								
Bulky wastes properly disposed			x			x	x	
Ban on open burning adhered to at site								x
Dust controlled at site	x							
Salvaging at site occurs in accordance with regulations								
Surface water managed at site					x			
Final slopes at least 1%, but not greater than 15%							x	
Satisfactory vegetative growth to prevent erosion on final soil cover								
Adhere to regulation ban on untreated leachate discharge to surface	x							
		x		x		x		

2. TYPES OF WASTE AND AMOUNTS IN TONS/DAY

	Clear- view '71/'72	Rine- hart '71/'72	Sweeny '71/'72	Rhoads '71/'72	Blosen- ski '71/'72	St. Michael '71/'72	Parkes- burg '71/'72	Haver- ford '71/'72
Agricultural waste								
Commercial waste	330	42	2		8	150		
Construction and demolition	30	42	5			3		5
Domestic and household waste	350	42	7	30	26		8	8
Industrial waste		17	15			10		
Park and beach waste								
Patient care institution waste					6			
Septic tank waste								
Sewage treatment plant and plumbing station waste								
Street and alley waste	20							2
Tree and landscaping waste		2	8					
Total	730	145	37	30	40	163	8	15

3. INSPECTORS' ANSWERS TO QUESTIONNAIRE

When was site first opened	c.1955	20+ yrs.	10-20 yrs.	30-40 yrs.	Ap. '71	c.1962	30-40 yrs.	c.20 yrs.
When will it be closed	?	?	action pending to close	w/in yr. if leach- ate not fixed	?	should have closed this year	3 more years	1-2 yrs.

Previous use of land	Clear-view '71/'72	Rinehart '71/'72	Sweeny '71/'72	Rhoads '71/'72	Blosen-ski '71/'72	St. Michael '71/'72	Parkes-burg '71/'72	Haverford '71/'72
	pig farm	pasture	quarry	farm	septic tank dump	sandpit	quarry	dump for incinerator
Future use of land	restaurant, ski slope?	?	storage sheds	plant soybeans	?	athletic field	park?	?
Operated by:	private	private	private	private	private	private	gov't	gov't

Problems due to disposal site: 1 = not important; 2 = fairly bad; 3 = very bad

Truck traffic and noise	1	1	1	1	2	1	1	1
Litter dropped from trucks	1	1	1	1	2	1	1	1
Paper blowing out of site	3	1	1	2	3	2	1	1
Rodents	2	1	1	1	1	1	1	1
Smells	1	1	1	1	2	2	1	1
Smoke	1	1	1	1	1	1	1	1
Insects	2	1	2	1	2	1	1	1
Noise from operation site	1	1	1	1	2	1	1	1
Pollution of surface and ground water	2	1	2	3	-	2	1	2
Dust	3	1	1	1	2	1	1	1
Other	bothers all who live nearby		slope problems, doesn't cover			lack of cover	pools of runoff water	bulky items fall into creek

4. OTHER DATA ON PHYSICAL CHARACTERISTICS

	Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael burg	Parkes-Haver- ford
Trucks per day:							
Small	5		15	7			
Medium	32		15	7		15	6
Large	88	30		7	35-40	40	
Total	125	30	30	21	35-40	15	6
Visibility from:							
North	yes	no	no	yes	no	yes	no
South	yes	yes	yes	no	yes	yes	no
East	yes	no	yes	yes	yes	no	no
West	yes	no	no	yes	no	yes	yes
Soil type	filling on fill	Rea- ville	oil satu- rates soil	Reaville fair - lots of rock frag- ments	Edge- mont Channery hit rock very quickly	Coastal allu- vium	Bedford silt loam ?
Cover material	gets cover from Re- dev'mt Authority, oil soaked sometimes	Kea- ville	?	sandy soil hailed in	poor soil for cover, might be too much rock	Coastal allu- vium	Bedford silt loam ?
Area of landfill in acres:							
Total area of land owned	55-60	83	3-4	60	12	30	3.86
Area currently disrupted	50	3-4	3-4	4-5	12	1	3.86
							≤5
							≤5

APPENDIX B
TABULATION OF RESPONSES:
KNOWLEDGE OF LANDFILL
(Per cent)*

		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michaels	Parkes- burg	Haver- ford
Know of landfill's existence (questions 1,2):	yes	80	92	81	93	91	92	84	58
	no	20	8	19	7	9	8	16	42
Know when opened (question 5):	yes	25	20	18	17	56	45	0	12
	no	75	80	82	83	44	55	100	88
	(no answer)	(4)	(1)	(2)	(0)	(1)	(3)	(4)	(0)
Know when closed (question 5):	yes	4	1	10	1	0	8	8	0
	no	96	99	90	99	100	92	92	100
	(no answer)	(8)	(0)	(9)	(1)	(4)	(10)	(4)	(13)
Know previous use (question 6):	yes	37	34	55	49	53	58	46	20
	no	63	66	45	51	47	42	54	80
	(no answer)	(7)	(0)	(0)	(0)	(0)	(4)	(4)	(2)
Previous use (question 6):	farm	12	74	56	87	3	5	68	12
	undeveloped	72	19	25	11	52	16	16	63
	homes	16	0	5	2	15	0	0	0
	lake, quarry	0	0	11	0	0	77	16	0
	cesspool, other	0	7	3	0	40	2	0	25
	(no answer)	(64)	(65)	(55)	(52)	(48)	(44)	(52)	(81)
Know future use (question 7):	yes	18	8	33	15	3	49	0	8
	no	82	92	67	85	97	51	100	92
	(no answer)	(22)	(5)	(5)	(1)	(13)	(5)	(15)	(10)
Future use (question 7):	park	27	0	0	13	0	11	0	33.3
	industry	2	0	0	0	0	2	0	33.3
	housing	69	100	92	73	100	8	0	0
	athletic field	0	0	0	0	0	49	0	0
	school, hospital, other	2	0	8	14	0	30	100	33.3
	(no answer)	(74)	(92)	(69)	(85)	(97)	(52)	(96)	(93)
Hear about landfill from (question 7):	public officials	13	4	7	0	12	5	7	0
	newspapers	34	40	14	25	61	28	48	21
	neighbors	34	23	39	38	71	40	41	31
	realtors	3	1	3	0	0	1	0	2
	trashmen	1	10	6	11	4	0	0	0
	community organizations	18	0	1	6	7	8	0	0
Landfill operating when moved in:	yes	71	80	77	92	43	52	94	94
	no	29	20	23	8	57	48	6	6
	(no answer)	(10)	(9)	(18)	(5)	(5)	(7)	(4)	(17)

*Percentages for all categories except "no answer" are based on only those who answered the specific question. Percentages for "no answer" category are based on all those who knew the landfill existed.

		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michaels	Parkes- burg	Haver- ford
Knew it was operating (question 11):	yes no (no answer)	54 46 (31)	74 26 (25)	43 57 (30)	67 33 (11)	56 44 (58)	55 45 (50)	87 13 (11)	55 45 (15)
Lived near landfill before (question 15):	yes no (no answer)	9 91 (3)	5 95 (1)	7 93 (1)	8 92 (2)	8 92 (1)	4 96 (1)	13 87 (11)	7 93 (0)
Visited landfill (question 17):	yes no (no answer)	29 71 (4)	29 71 (0)	30 70 (0)	40 60 (2)	22 78 (0)	36 64 (3)	52 48 (0)	19 81 (0)
Trucks pass house (question 18):	yes no (no answer)	18 82 (3)	71 29 (0)	29 71 (0)	55 45 (3)	53 47 (4)	12 88 (5)	19 81 (0)	0 100 (0)
Landfill operated by (question 19):	government private don't know (no answer)	8 62 30 (2)	0 81 19 (1)	0 73 27 (0)	0 91 9 (1)	3 84 13 (0)	4 63 33 (1)	89 4 7 (0)	49 10 41 (2)
Origin of trash (question 20):	only this twshp. this & other twshps. only other twshps. don't know (no answer)	6 46 6 42 (3)	4 66 1 29 (0)	5 46 7 42 (1)	15 51 1 33 (1)	3 72 4 21 (1)	9 49 2 40 (1)	82 0 18 0 (0)	31 10 28 31 (0)
Why was landfill put in the neighborhood (question 30):	functional reasons vacant land neighborhood had no power (no answer)	55 43 2 (66)	76 24 0 (73)	92 8 0 (69)	85 15 0 (60)	96 4 0 (68)	98 0 2 (49)	50 50 0 (93)	67 33 0 (78)

APPENDIX C
TABULATION OF RESPONSES
ATTITUDES TOWARDS LANDFILL

Reproduced from
best available copy.

		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael	Parkes- burg	Haver- ford
Landfill has an important effect on neighborhood (question 3):	yes	79	22	49	30	77	58	27	52
	no	21	78	51	70	23	42	73	43
	(no answer)	(2)	(0)	(4)	(2)	(4)	(6)	(4)	(5)
How does land- fill effect the neighborhood (question 3):	greatly improves	0	12	1	1	1	1	16	2
	slightly improves	.5	0	2	2	0	5	0	2
	has little effect	17	71	48	66	25	42	64	45
	slightly detri- mental	15	14	33	18	14	22	20	22
	very detri- mental	67.5	3	16	13	58	30	0	29
	(no answer)	(4)	(5)	(0)	(3)	(0)	(2)	(4)	(0)
Knowledge of the disposal site affected decision to move in (question 12):	substantially increased desire to move in	1	0	0	0	0	0	0	0
	slightly increased desire to move in	0	0	0	0	0	0	0	0
	had no effect effect	82	98	88	97	90	94	100	100
	slightly decreased desire to move in	12	0	12	3	5	6	0	0
	substantially decreased desire to move in	5	2	0	0	5	0	0	0
	(no answer)	(61)	(46)	(69)	(39)	(75)	(71)	(22)	(52)
If had known about disposal site, would have moved in (question 13):	definitely not	24	0	6	3	18	9	17	10
	probably not	22	3	14	25	22	15	0	15
	would have made no difference	53	97	80	72	60	76	83	75
	little more likely	1	0	0	0	0	0	0	0
	much more likely	0	0	0	0	0	0	0	0
	(no answer)	(46)	(57)	(38)	(63)	(30)	(33)	(78)	(52)

		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael	Parkes- burg	Haver- ford
Considering site now, would move in (question 14):	definitely								
	not	31	1	13	2	28	9	4	5
	probably								
	not	14	4	8	7	15	8	0	5
	would have								
	made no								
	difference	54	94	79	91	57	83	96	90
	little more								
(question 22):	likely	.5	0	0	0	0	0	0	0
	much more								
	likely	.5	1	0	0	0	0	0	0
	(no answer)	(14)	(1)	(3)	(2)	(3)	(2)	(0)	(2)
Effect site has had on property value (question 22):	worth much								
	more	0	0	0	0	0	0	4	0
	worth a little								
	more	2	0	1	2	1	0	5	2
	site has no								
	effect on								
	house								
	value	59	94	85	94	64	91	86	88
(question 22):	worth a little								
	less	23	6	13	3	27	9	5	10
	worth much								
	less	16	0	1	1	8	0	0	0
	(no answer)	(24)	(13)	(11)	(12)	(14)	(11)	(18)	(5)
Problems due to disposal site (question 26):									
truck traffic & noise									
(question 26):	not important	76	83	67	72	43	82	96	93
	fairly bad	6	7	14	8	13	10	4	5
	very bad	18	10	19	20	44	8	0	2
	(no answer)	(3)	(0)	(0)	(0)	(1)	(2)	(0)	(0)
litter dropped from trucks									
(question 26):	not important	77	87	70	85	48	82	89	100
	fairly bad	23	7	9	7	10	9	7	0
	very bad	20	6	21	8	42	9	4	0
	(no answer)	(4)	(1)	(0)	(0)	(0)	(3)	(0)	(2)
paper blowing out of site									
(question 26):	not important	73	100	89	76	69	79	96	95
	fairly bad	8	0	6	8	5	10	4	5
	very bad	19	0	6	16	26	11	0	0
	(no answer)	(3)	(1)	(0)	(0)	(0)	(4)	(0)	(0)
rodents									
(question 26):	not important	49	96	85	86	86	74	82	88
	fairly bad	9	0	2	5	4	8	7	7
	very bad	42	4	13	9	10	18	11	5
	(no answer)	(3)	(0)	(0)	(0)	(0)	(2)	(0)	(0)

		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael	Parkes- burg	Haver- burg
smells	not important	21	91	72	72	44	46	81	78
	fairly bad	7	1	8	6	9	12	11	10
	very bad	72	8	20	22	47	42	8	12
	(no answer)	(3)	(0)	(0)	(0)	(0)	(2)	(0)	(0)
smoke	not important	43	99	82	84	68	85	83	74
	fairly bad	15	1	8	9	13	10	7	12
	very bad	42	0	10	7	19	5	11	14
	(no answer)	(4)	(0)	(0)	(0)	(1)	(3)	(0)	(0)
insects	not important	45	100	85	90	77	82	82	74
	fairly bad	16	0	8	5	15	11	7	12
	very bad	39	0	7	5	8	7	11	14
	(no answer)	(4)	(1)	(1)	(0)	(1)	(4)	(4)	(0)
operation noise	not important	79	96	85	88	81	83	100	62
	fairly bad	10	3	5	9	11	13	0	26
	very bad	11	1	10	3	8	5	0	12
	(no answer)	(5)	(0)	(0)	(0)	(0)	(3)	(0)	(0)
just knowing it's there	not important	46	95	81	91	46	66	93	74
	fairly bad	16	1	9	6	20	14	7	9
	very bad	38	4	10	3	34	20	0	17
	(no answer)	(3)	(0)	(0)	(0)	(0)	(3)	(0)	(0)
pollution of surface and ground water	not important	65	94	93	76	80	81	93	71
	fairly bad	6	1	1	13	5	15	0	5
	very bad	29	5	6	11	15	4	7	24
	(no answer)	(4)	(1)	(0)	(0)	(3)	(4)	(0)	(0)
dust	not important	50	99	81	95	89	67	100	88
	fairly bad	14	0	10	5	6	14	0	5
	very bad	36	1	9	0	5	19	0	7
	(no answer)	(5)	(0)	(0)	(0)	(3)	(4)	(7)	(0)
other	not important	81	94	88	99	83	79	98	50
	fairly bad	1	0	5	0	6	11	0	21
	very bad	18	6	7	1	11	10	2	29
	(no answer)	(51)	(61)	(46)	(59)	(54)	(58)	(56)	(67)
These specific problems affect									
(question 28):									
health	most affected	72	55	50	59	44	64	80	78
	somewhat								
	affected	17	27	12	18	26	24	0	17
	least								
	affected	11	18	38	33	30	12	20	5
	(no answer)	(33)	(86)	(58)	(72)	(42)	(70)	(82)	(57)

	Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael	Parkes- burg	Haver- ford
property values								
most affected	10	34	31	19	36	40	40	5
somewhat affected	49	22	55	31	32	32	0	17
least affected	41	44	14	50	32	58	60	78
(no answer)	(35)	(88)	(64)	(74)	(43)	(72)	(82)	(57)
appearance of neighborhood								
most affected	24	22	33	27	24	33	0	21
somewhat affected	32	22	24	50	36	39	50	63
least affected	44	56	43	23	50	28	50	16
(no answer)	(36)	(88)	(59)	(74)	(46)	(70)	(85)	(55)
Have noticed any change in way the landfill is operated (question 29):								
yes	58	39	58	40	54	55	67	36
no	42	61	42	60	46	45	33	64
(no answer)	(2)	(0)	(0)	(0)	(1)	(1)	(0)	(0)
What changes (question 29):								
improved	22	81	67	91	50	74	100	87
worse	78	19	33	9	50	26	0	13
(no answer)	(59)	(65)	(55)	(41)	(51)	(48)	(33)	(64)

APPENDIX D

PERSONAL CHARACTERISTICS OF RESPONDENTS

		Per cent*					
		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael Parkes- burg Haver- ford
Years of school (question 33):	<12	73	86	64	62	81	75
	12 - 16	23	13	31	26	15	12
	<16	4	1	5	12	4	13
	(no answer)	(10)	(4)	(3)	(4)	(1)	(11)
							(0)
Socioeconomic index (question 34):	<20	17	42	13	27	48	23
	20-40	47	34	35	20	33	39
	40-60	19	13	22	16	12	19
	60-80	13	11	19	30	5	15
	80-100	4	0	11	27	2	4
	(no answer)	(4)	(1)	(4)	(1)	(3)	(4)
							(0)
Household income (question 35):	<\$5,000	10	22	8	5	31	8
	\$5,000-7,500	37	57	19	33	38	46
	\$7,500-12,500	33	10	45	48	19	23
	\$12,500-17,500	14	6	21	12	6	15
	\$17,500-22,500	4	5	4	2	4	0
	>\$22,500	2	0	3	0	2	8
	(no answer)	(31)	(36)	(41)	(26)	(33)	(52)
						(28)	(48)
Property value (question 24):	<\$15,000	26	14	8	0	16	30
	\$15,000-20,000	47	17	18	8	20	10
	\$20,000-25,000	13	21	12	24	28	20
	>\$25,000	14	48	62	78	36	40
	(no answer)	(54)	(62)	(38)	(50)	(68)	(63)
						(25)	(29)

		Per cent							
		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael	Parkes- burg	Haver- ford
Moved to neighborhood because of (question 9):	good schools	31	14	46	30	30	49	4	49
	cost of housing	59	18	35	23	15	57	27	49
	type of neighbors	37	12	14	12	14	23	7	21
	good public trans- portation	25	1	8	5	3	17	0	21
	closeness to job	45	36	42	49	27	47	19	28
	attractive neighborhood	59	48	54	53	38	40	29	61
	area not very built up	25	67	39	56	54	12	37	18
	near family & friends	42	30	28	15	42	24	37	21
	own house?	84	88	98	94	87	97	89	100
	rent house? (no answer)	16 (3)	12 (1)	2 (1)	6 (0)	13 (0)	3 (1)	11 (0)	0 (0)
Do you (question 21):	< 5	42	26	24	56	35	28	22	19
	5-10	9	19	25	18	17	22	11	31
	10-15	17	13	26	12	17	10	30	17
	15-25	18	25	19	9	18	40	22	24
	> 25	14	17	6	5	13	0	15	9
Years lived in home (question 4):									

PHYSICAL RELATIONSHIP BETWEEN SITE AND RESPONDENT:

PHYSICAL RELATIONSHIP BETWEEN SITE AND RESPONDERS.									
		Per cent*							
		Clear- view	Rine- hart	Sweeny	Rhoads	Blosen- ski	St. Michael	Parkes- burg	Haver- ford
Can see:	only shrubbery	2	1	42	17	4	8	7	2
	buildings/ machinery	1	8	0	7	1	3	7	9
	operation itself	29	5	15	30	17	17	23	36
	nothing	64	86	73	46	78	72	63	53
	(no answer)	(2)	(0)	(0)	(2)	(0)	(3)	(0)	(0)
Distance to site:	<500'	3	8	46	0	7	12	4	35
	500' - 1000'	13	12	35	9	17	31	33	57
	1000' - 1500'	14	6	10	35	10	27	15	4
	1500' - 2500'	45	30	9	54	19	29	22	4
	>2500'	25	44	0	2	47	1	26	0
On truck route:	yes	7	52	26	57	49	3	11	0
	no	93	48	74	43	51	97	89	100

*Per cent for all categories except "no answers" based on only those who answered the specific question. Per cent for "no answer" category based on all those who knew the landfill existed.

APPENDIX E
NOTES ON EACH OF THE LANDFILLS

Clearview

Clearview is the largest of the landfills studied. It is now 80' high and the owner plans to continue until it is 100' high. Clearview has had a bad record until fairly recently. . . The owner claims he has permission from the city to fill land. . . Has gone to court once for preliminary injunction (1971) - technically still in court - consent order negotiated later - hasn't really submitted plans - court order required he submit topo maps, operational plans, etc. - needs more work on plans for reseeding and planting. . . He used to burn, probably hasn't for some time. . . Started covering about March, 1972 - has done a lot of final grading on the Philadelphia side, where he is almost finished except for planting. . . State would like to close the site. Located in Philadelphia on boundary between it and Colwyn pownship and Darby Township. More visible from Colwyn. Rundown areas near landfill; some of them to the east used for dumping. Nuisances in the general vicinity: petroleum refinery and storage, International Airport.

Rinehart (Pottstown)

Always run fairly well, but now very good. . . Used to have leachate problem about a year ago, but now has good leachate collection system. . . Daily cover looks like final cover - only two foot lifts. . . The Rinehart brothers live next to the landfill and are popular with the neighbors. Knowledge of this landfill is very widespread, especially because it was widely publicized after flood Agnes, 1972.

Sweeny

History of noncooperation - no engineer or plans. . . Oil saturates ground from broken oil pipe - has had this problem fairly straight through. . . Township complains about him - took him to court on zoning - lost - if he expands he'll have to fight - since last October, 1971, case being prepared - only one resident complaint recently. . . Whole area has already been filled, but he's filling on fill - he wants to start filling in trenches on the property behind him - wants to lease the land . . . He says he doesn't take garbage, but probably takes a little. The owner lives in the neighborhood next to the landfill. Located at edge of two townships.

Rhoads

Until two years ago was not covering. . . Burning frequently until a year ago. . . Today leachate is the major problem (moderate problem). His engineer is working on it - has to work with the local authority about disposal of leachate. Blowing paper used to be the worst problem. William Rhoads lives in the midst of the neighborhood that was interviewed, and is considered an outstanding and model citizen ("a good Christian") by the majority of his neighbors. Once, when his dump used to catch fire frequently, Rhoads threw a clambake for the fire department. Many people were reluctant to answer the questionnaire since they felt the information would be used against Rhoads, despite our assurances to the contrary. As a result people were willing to overlook "little nuisances" such as trucks continually passing (thundering) by their house. Word seems to have gotten around the neighborhood that we were coming, one woman even saying, "Mr. Rhoads told me to expect you." . . . Rhoads uses his house as the check-in point for all trucks and at night parks his compactors next to his house and near his neighbors lawns. Few complained about this.

Blosenski

West Caln Township landfill closed down by the state in 1970. This was used as a social gathering place and was considered a well-run site by the residents in comparison to Blosenski's which opened shortly thereafter. Blosenski is resented by people, who assume he was able to open because of political pull. During summer of 1971 a summons filed because of burning and general violations. In October 1971 fire was still burning - turned over to Pennsylvania Environmental Strike Force - suit filed against Blosenski in March 1972. Had hearing in April - didn't improve within a month - filed contempt of court in June - hearing again August 12. Fairly bad noncompliance, but could be worse - must be in compliance by September 11. Many township and resident complaints. . . Has had no extermination program in the past, so possibly there are rats. . . Supposed to pay \$2,000 fine at end of August for contempt of court, but improved greatly. Then in September there were equipment problems - the site looked very bad - almost none of the equipment was working at the last report and there was more uncovered refuse than ever before - the Strike Force is going to sue for contempt or increase the fine immediately. Area is somewhat rural, scattered homes and "mobile homes". Landfill is on main road, in view of many travelers.

Saint Michael

Fairly well run to poorly run. . . Used to be some surface leachate which is now mostly taken care of - at one time covered directly over leachate. . . Has odor complaints. . . Hasn't turned in operating plans for landfill to state. . . Were supposed to close in May, 1972. Owned by St. Michael's of the Archangel Church - at least 50% of the people interviewed belonged to the parish, which may have influenced their answers. The church is making money and has promised the residents that the future use of the landfill will benefit the neighborhood (rumor has it that it will be an athletic field, hospital, or school annex). Neighborhood children use landfill as a playground. Landfill adjacent to Levittown Lake so many people have an unimpeded view of landfill.

Parkesburg

This is the smallest and least intensely used site. Owned and run by Borough. Now fairly well run, but was very poorly run. Stopped burning in 1968. . . Were only covering once a week. Used to have bad problem of blowing paper and scavenger birds. . . Had more surface water. . . Has no fence. . . Never had any legal action. . . Well run now - improvement last fall. . . Farmer complained runoff was hurting his fields. Located on edge of borough.

Haverford

A municipal dump, primarily for bulky objects such as major household appliances. Hasn't submitted any plans. . . Just applied for a permit. . . No changes. . . Are starting to reclaim some metal, so it sometimes accumulates - should be moved out about once a week. . . Occasional fires. . . Located in Haverford Township on township boundary, but it can only be seen from the Broomall side where most of the resident complaints are centered. Located next to incinerator, which has been closed down for about 7 years. Many people either knew only of the existence of the incinerator or confused previous problems of the incinerator with the landfill.

Questionnaire

Hello, I'm from the Regional Science Research Institute, which is a non-profit research corporation located in Philadelphia. We are conducting a survey about solid waste management.

1. Can you tell me where the nearest trash disposal site is located?

2. (if doesn't identify the site, say) Do you know the disposal site at _____?

(if no, conclude interview)

3. Overall, do you think that this site has an important effect on the neighborhood? yes _____ no _____

Choose one:

Greatly improves neighborhood _____

Slightly improves neighborhood _____

Has little effect _____

Slightly detrimental to neighborhood _____

Very detrimental to neighborhood _____

4. How long have you lived here? _____

5. Do you know when this trash disposal site was opened? yes _____ no _____

When? _____

When will it be closed? _____ doesn't know _____

6. Do you know what the site was used for before? yes _____ no _____

What? _____

7. Do you know what use is proposed after the site is closed?

What? _____

In general, how did you get information about the landfill?

Choose one or more:

Statements of public officials _____
Newspapers _____
Neighbors _____
Realtors _____
People in the trash disposal business _____
Community organizations _____

8. Do you consider the future use an improvement over the use before this became a disposal site?

Choose one:

Great improvement _____
Slight improvement _____
No difference _____
Slightly worse _____
Much worse _____

9. What factors were most important in your decision to move into this neighborhood? Please rank the 4 most important factors, 1 to 4.

* Good schools _____
Cost of housing _____
Type of neighbors _____
Availability of public transportation _____
Closeness to job _____
Physically attractive neighborhood _____
Area not very built up _____
Near family, friends _____

10. Was the disposal site operating when you moved in? yes ___ no ___

11. If "yes", did you know about it? yes _____ no _____
(go to 12) (go to 13)

12. If "yes", how did the knowledge of the disposal site affect your decision to move in? (then go to 14)

Substantially increased my desire to move in _____
Slightly increased my desire to move in _____
Had no effect _____
Slightly decreased my desire to move in _____
Substantially decreased my desire to move in _____

13. (For those who did not know, or for whom site was not in operation)
If you had known about the disposal site, would you have moved in?
- | | (13) | (14) |
|---|-------|-------|
| Choose one: | | |
| Definitely not | _____ | _____ |
| Probably not | _____ | _____ |
| Wouldn't have made any difference | _____ | _____ |
| Would have been a little more likely to
to move in | _____ | _____ |
| Would have been much more likely to move in | _____ | _____ |
14. Considering the disposal site as it is now, would you move in?
15. Did you ever live near a trash disposal site before you moved here?
yes _____ no _____
16. Can you see the site from your house? yes _____ no _____
If so, what can you see?
- | | |
|--|-------|
| Only shrubbery surrounding -- can't tell | _____ |
| it is a disposal site | _____ |
| Buildings or machinery only | _____ |
| Disposal operation itself | _____ |
17. Have you actually visited the landfill operation? yes _____ no _____
18. Do trucks going to and from the landfill pass in front of your house?
19. Is this disposal site operated by the government or by a private company?
government _____ private company _____ don't know _____
20. Do haulers bring trash from:
- | | |
|--|-------|
| Only this township | _____ |
| This township and other townships | _____ |
| Other townships only (not this township) | _____ |
| Don't know | _____ |
| No answer | _____ |
21. Do you own or rent your house?
22. (Ask owner): What effect would you say the disposal site has had on the value of your property?

Property worth much more since disposal began _____
 Property worth a little more since disposal began _____
 Disposal has had no effect on house value _____
 Property worth a little less since disposal began _____
 Property worth much less since disposal began _____

23. (Ask renters): What effect do you think the disposal site has on your rent?

Caused a substantial increase in rent _____
 Caused a small increase in rent _____
 No effect on rent _____
 Caused a small drop in rent _____
 Caused a substantial drop in rent _____

24. Could you make a rough estimate of this effect in dollars? (show card)
 owners \$_____ capital value. renters \$_____ per month.

25. How does that compare with the current value (rent) of your house?
 is _____ % of it or current value (rent) is \$_____

26. In your experience, to what extent are the following important problems because of the disposal operation.

Very	Fairly	Not
<u>Bad</u>	<u>Bad</u>	<u>Important</u>

- a. truck traffic and noise _____
- b. litter dropped from trucks on neighborhood streets _____
- c. paper blows out of disposal site _____
- d. rodents _____
- e. smells _____
- f. smoke _____
- g. insects _____
- h. noise from site operation _____
- i. just knowing it is there _____
- j. pollutes surface and ground water _____
- k. dust _____
- l. other _____

27. In your experience, which of the above problems is the worst;

Second worst:

Third worst:

28. These specific problems may contribute to more general effects.
Which of the following effects have affected you most? (please
rank 1: most important)

Health _____
Property values _____
Appearance _____

29. During the time you have lived here, have you noticed any basic
change in the way it has been operated? yes _____ no _____

If yes, please elaborate _____

30. Why was the disposal site put in this neighborhood?

31. Number of adults in household _____

32. Number of children in household
between 0 - 6 years _____
6 - 12 years _____
12 - 18 years _____

33. Education of head of household
high school _____ years
college _____ years
higher _____ years

34. Occupation _____

35. Yearly income of household (exclude young adults living at home)

Under \$5,000 _____
\$ 5 - 10,000 _____
10 - 15,000 _____
15 - 20,000 _____
20 - 25,000 _____
Over \$25,000 _____

To be filled in by interviewer:

Address _____

VII. EFFORTS AT INTERMUNICIPAL COOPERATION FOR SOLID WASTE DISPOSAL: WHY THEY FAIL*

Introduction

Within most large metropolitan areas there exists a complex network of local governments. In the typical network responsibilities for public functions are divided among numerous distinct, but sometimes overlapping, units of government. In recent years much attention has been focussed upon this fragmentation of responsibilities.¹ A common theme is that fragmented metropolitan areas are handicapped; they are unable to solve some of the more pressing urban problems they face. Quite naturally, a fairly large literature has developed which focusses upon "solutions" to the problem of fragmentation. The premise of much of this literature is that the system of governments in metropolitan areas needs to be reorganized and, accordingly, there are numerous suggestions for reshaping metropolitan government.²

The discussions of metropolitan reorganization raise, however, an important but unanswered question. Namely, if there exists a system of governments which, by a set of accepted criteria, is better than the current system, why does the current system persist? The objective of this paper is to begin to answer this question. To do so it is necessary to explore more fully the process whereby political arrangements are chosen within metropolitan areas. It is necessary to point out the incentives for choosing one or another organization of governments as well as to describe how the incentive system could be structured so that optimal choices result.

In the next section I briefly summarize some important components of the debate over the nature of an optimal governmental system for metropolitan areas, and I apply this to the area of solid waste disposal. I conclude that, in many cases, the best arrangement for providing

*Chapter VII written by Jane Gilbert.

solid waste disposal services would involve intermunicipal agreements at less than the county level.

In reality, however, such governmental organizations are rare. To find out why this is the case I develop four case histories which describe the efforts of four groups of municipalities to form intermunicipal agreements for disposal. These case histories are described in section III.

In section IV I turn to a more formal game theoretic analysis of the municipal choice process. Municipalities, it is assumed, behave as rational actors: they choose alternatives which lead to outcomes with the highest payoffs. The parameters of the choice process -- alternatives, outcomes, payoffs -- are specified and their specification is rooted in the case study material. The purpose of the analysis is to answer the following questions: (1) if municipalities behave as rational actors, what form of governmental organization (for providing disposal) can we expect them to choose? (2) how can the parameters of the choice process be changed so that rational choice leads to an optimal organization of government?

In general, this paper purports to show that it is rational for municipalities to choose a suboptimal system for providing solid waste disposal. Fragmentation is a reasonable choice under the current system of constraints. To encourage greater coordination among municipalities, it will therefore be necessary to remove the disincentives for this choice.

Political Organization

In Metropolitan Areas

A fragmentation of responsibilities - such as that found in most large metropolitan areas - supposedly makes it difficult to provide public services efficiently. Inefficiency results for a number of reasons. For many public services it is argued that there are significant economies of scale.³ To provide services for only a small population means that the unit cost is relatively high; to provide these services on a larger scale would reduce the unit cost. Metropolitan areas are, however, divided into a large number of local governments. When each of these units of government individually undertakes provision of goods or services it is much more expensive than if the same were provided on a larger scale. Hence, fragmentation leads to higher expenditures.⁴

A second reason for inefficiency is related to the nature of problems in metropolitan areas. Rarely do these problems end at the boundaries of political units. More often than not pressing problems extend beyond individual boundaries and "spill over" into other nearby communities. Consequently the decisions made (or not made) by one unit of government produce externalities. And, as has been carefully demonstrated in many places, the presence of externalities leads to inefficient choice.⁵

The existence of externalities raises, however, a second set of problems related to citizen representation. If the decisions made (or not made) by one municipality affect citizens in a second municipality then the latter group should have a voice in the decision making process. Yet, when there are two (or more) separate governments in the area, this does not occur. Rather, citizens find that

their welfare is being affected by choices made by other municipalities and, more important, they have no means of participating in that choice process. Thus choices in metropolitan areas tend to be responsive to only a subset of all persons affected by a problem.

An extreme division of responsibilities among a number of overlapping units of government further impedes the participatory process. A single citizen may find he resides within one school district, a second sewerage district, a third police district, a fourth planning area and so on. In short, there is no single government which can be held accountable for problems. Instead a citizen must complain to one set of officials about schools, to a second set about sewers, etc. The complexity of this situation creates difficulties for the average citizen. Certainly he must be master of much more information than if he resided within a municipality that were responsible for all (or most) public services. Participation is difficult in situations such as these and in the long run the responsiveness of the various governments to citizen preferences declines.

To remedy the problems caused by fragmentation some have suggested the implementation of a single multi-functional metropolitan area government. Since this new government would be larger in scale and scope than any of the individual municipalities it is suggested that it would be able to combat problems of inefficiency and representation at the same time; externalities would be internalized, services would be provided on an appropriate scale, decisions made about large problems would take into consideration all persons affected, and citizens would readily know where responsibility lies.

The notion of a single metropolitan body to replace (or supplement) the existing system of overlapping and fragmented responsibilities has received wide attention. The solution does, however, have certain deficiencies and these are discussed quite succinctly in a well known paper by Ostrom, Tiebout and Warren who contend that a "polycentric" form of government has certain desirable attributes.⁶

First, both externalities and economies of scale vary from one service to another. The group of persons affected by playground decisions may be much smaller than the group affected by decisions concerning mass transit. For the former it is possible that there are no significant externalities when decisions are made by a neighborhood government. For the latter, however, a metropolitan or regional government may be needed to internalize external effects. Similarly, the optimum scale for providing one service may be less than that for providing a second service so that for some functions economies of scale may be maximized at less than the metropolitan level.

Thus, a single metropolitan government may not be necessary for the efficient provision of all services. Furthermore such a governmental system could itself lead to inefficiencies and unresponsiveness. With respect to economies of scale, production of a service on too large a scale may be just as costly as its production on too small a scale.

With regard to externalities, Ostrom et. al. contend that the decision making unit should include all those affected by a decision, but no others. If "unaffected persons are given a voice in the process, capricious action may result. The total population in a city

of three million population may not be an appropriate decision-making mechanism in planning a local playground."⁷ It may be, for example, that citizens in one small part of the metropolitan area are interested in financing and constructing a recreational facility, but that residents in the remainder of the area are not. If such recreational decisions are made only at the metropolitan level then those citizens who wish the new facility are likely to be deprived of it even though these citizens would be willing to bear its costs. In general smaller decision-making units are more likely to permit groups of citizens with different preferences to make different choices among services. A single metropolitan area government could tend to minimize this freedom of choice by enforcing a single standard of living upon all residents. And, it would do so in cases where this is not required for the sake of efficiency or representation.

Organization for the Provision of Solid Waste Disposal.

Based upon the preceeding discussion I assume that the best political organization for providing one or more services will vary in size with the nature of the goods and services it produces. For certain classes of services an individual municipality is an inappropriate decision-making unit as it is neither large enough to internalize all consequences of its decision nor to capture production economies. A regional or county government may be equally inappropriate in some instances, as it is also inefficient to produce services on too large a scale. Moreover, large decision-making units tend to prevent a certain freedom of choice so that where they are not needed for purposes of efficiency they are not clearly desirable.

The implication of this argument is that in some cases the best government may be, in size, somewhere between the single municipality and the entire metropolitan region. In some cases it may be optimal for a number of municipalities to coordinate their activities and to provide a service jointly. Thus, the best decision-making unit would include a number of municipalities.

Where it is desirable, there are numerous ways in which separate municipalities can coordinate their decisions or share responsibilities. Special districts and/or authorities, inter-governmental contracts, and informal cooperative arrangements are some examples.⁸ All, however, require the cooperation of individual municipalities. And, there is limited evidence that such cooperation is not simple to achieve.

One mode of cooperation involves the creation of a special district - a single purpose government usually (though not always) encompassing more than one unit of local government. According to a leading expert in this field, special district governments are proliferating at a rapid pace in the U. S.⁹ Nevertheless there do seem to be many instances in which greater cooperation (such as a special district) would be desirable and yet municipalities choose instead to "go it alone" or to cooperate to a minimal extent. In their report on Intergovernmental Responsibilities for Water Supply and Sewage Disposal in Metropolitan Areas, the Advisory Commission on Intergovernmental Relations finds:

Some utility districts are quite large... Most, however, are quite small. Prior to the creation of the Municipality of Metropolitan Seattle, 82 percent of the sewer districts in suburban Seattle were less than two square miles in area, and almost half less than one-half a square mile in area.

Fragmentation ... has had an adverse affect on public health in a number of metropolitan areas. Small municipalities and sewer districts often fail to process wastes at all, or treat them only inadequately. Many lack the resources to finance long outfall lines ... The lack of coordination also affects resource utilization across local boundaries. Depletion of the ground water reserves ... is a common problem in suburban areas dependent on individual or community well systems.¹⁰

Thus, in this area of responsibilities the extent of coordination is insufficient.

Sewage and water supply decisions are certainly not unique in this respect. For many of the most commonly provided services (e.g. fire and police protection, transportation, hospital and medical care) benefits would accrue to more serious efforts at cooperation among municipalities.¹¹

These facts raise the central topic of this paper. If individual municipalities can benefit from cooperative arrangements, why aren't such arrangements more common? Why aren't serious efforts to coordinate activities pursued more vigorously? What is it about the world that inhibits cooperation? And, finally, what can be done, in a policy sense, to encourage cooperative arrangements where they are beneficial?

The research described here is devoted to an analysis of such questions in the area of solid waste disposal. For many types of disposal facilities cooperation would be desirable. Sanitary landfills require certain types of terrain and not all municipalities contain suitable sites. Incinerators are a relatively expensive method of disposal requiring a fairly large capital outlay. Smaller municipalities with a low volume of waste are rarely able to justify the

expense and a low volume of waste also means that the operating cost (on a per ton basis) will be quite high. It is thus somewhat inefficient for a single small municipality to provide an incinerator. However, it is most efficient for a number of small municipalities to do so jointly.

As technology improves and the need for more effective systems of disposal rises, it is likely that even more expensive facilities will be required. (The current popularity of transfer stations and recycling plants are evidence of this trend.) Thus, the small municipality is likely to find it even more difficult to undertake effective action alone in the future.

For many methods of disposal there do exist significant economies of scale. These, however, are offset by the quickly rising costs of hauling waste a longer distance for disposal.¹² Thus it may be quite inefficient for a large number of municipalities (e.g. all those in a county) to coordinate their activities. This means that in many cases an optimal unit for making decisions about solid waste disposal is likely to include a few cooperating municipalities. In this way it would be larger than a single municipality but smaller than a county wide or regional government.¹³

Case Studies in Cooperation for Waste Disposal

In order to find out more about the incentives and disincentives to inter-municipal cooperation for waste disposal I decided to explore the histories of past and present attempts at such cooperation. Identification of "cooperative efforts" has been most difficult.

In two of the four counties - Montgomery and Delaware -- the county government has assumed responsibility for solid waste disposal. Hence, there is no current reason for individual municipalities within these counties to consider joint or cooperative means of providing citizens with disposal facilities. In contrast, the role of the county in the other two counties -- Bucks and Chester - is almost negligible. Municipalities in these counties must deal with the disposal problem themselves and, accordingly, one would expect some attempts at intermunicipal cooperation to construct and operate disposal facilities. In addition, both counties contain a large number of relatively small townships and boroughs. One would expect that many of these municipalities are just too small to provide disposal individually on anything resembling an efficient scale. Again, cooperative agreements would appear reasonable. Yet, only four cooperative efforts have been identified--two in each county.

The following is a description of each of the four cooperative efforts.¹⁴

West Chester Joint Refuse Disposal Authority (WCJRDA)

The WCJRDA was formed in 1958-59. It is composed of five townships and the borough of West Chester. As is typical of most Pennsylvania areas designated as boroughs, West Chester has traditionally been more heavily settled and urban than the surrounding townships. (Table 1 gives the population of the individual municipalities that comprise the authority.)

Table 1

WCJRDA: Population of Member Municipalities

	1970	1960	% Change
West Chester Borough	19,301	15,705	22.9
East Goshen Township	5,138	1,694	203.3
West Goshen Township	12,858	8,214	56.5
East Bradford Township	3,260	1,713	90.3
Westtown Township	5,069	1,947	160.3
Birmingham Township	834	453	84.1

From: U.S. Bureau of the Census, Census of Population; 1970,
Number of Inhabitants - Pennsylvania.
 Subsequent tables based on same source.

For two reasons, it is probable that West Chester borough was the Key organizer of the authority. First, it is densely settled and did not have space within its boundaries to use for a landfill. To find adequate amounts of land it was necessary to look in nearby townships. Second, West Chester has traditionally provided its citizens with municipal refuse collection. Other municipalities have not. Thus the need for a landfill was probably more apparent to persons in West Chester than to those in other townships.

I have been told that persons in West Chester contacted persons in West Goshen (an adjacent township and the eventual site of the landfill) about jointly operating a landfill. Additional municipalities were then contacted. Since I was interested in the incentives for other municipalities to participate in this venture I asked why these townships would be interested in participating in the operation of a landfill. One person replied that in rural areas municipalities traditionally provided a dump for residents. Arrangements were very casual and many persons in such areas dumped their own trash on Saturday mornings. Thus, the townships may have felt that they could support a landfill in place of their own dumps and that this was part of their traditional responsibility. Of additional importance is West Chesters' centrality in the area. In many ways it was a leader and other municipalities were anxious to go along with it because of this.

With respect to organization, the Authority was arranged so that each member would make an initial monetary contribution based upon population. West Chester was the primary financier and contributed \$3200. Other townships contributed less. One paid only \$225 initially. This initial capital was used to purchase land and equipment. Operating costs were financed by users' fees.

One person was appointed from each municipality to the governing board and this group elected their own officers. A committee of one or two persons oversaw the operation of the site.

The site itself was managed on a day-to-day basis by a "farmer turned bulldozer operator" who was "well intentioned but terribly inefficient."

In January, 1968 problems began as a result of public complaints. The state charged the authority with running a bad landfill. There was a serious leachate discharge into a neighboring creek and the operation was generally unaesthetic.

A consultant-engineer was hired who took charge of the operation for the last two years of its life. According to him, the site was quite bad when he was first hired - a serious fire from uncovered refuse occurred one week after he began. He did, however, organize the digging and filling of trenches and rearranged the operation so that the leachate was minimized. There were few complaints during this period.

Though difficult to document, the landfill is estimated to have served about 40,000 persons over about 12 years. In all but its last year anybody could use it. In the last year when it was realized that space was running out an attempt was made to restrict usage to authority members. The landfill was closed due to lack of space in 1970-71.

The search for a new site began but was beset with difficulties. The state solid waste management act had been passed and requirements for licensing a site were most stringent. More than this, however, local opposition proved the biggest stumbling block.

At one point land in East Bradford was seriously considered. I have been given two different versions of why this failed to materialize.¹⁷ One person claims the land was purchased by the Authority but, approximately 20-25 citizens brought an injunction against the Authority and won in court so that the sale was aborted. A second person told me that the land was condemned by the Authority but that the zoning board would not grant an exception as needed for use as a landfill. Though one person did wish to challenge the zoning laws members of the Authority did not wish to pursue this. Rather they felt that if voluntary compliance did not come about they would forget about it.

The largest problem with the site in East Bradford seems to have been its poor access. Households along the only and narrow access road would have been greatly affected by compactor trucks using this road.

Numerous other attempts were made to find a site, with no success to date. The county was canvassed using aerial photos and actual site exploration. An appropriate site was found but it was quite distant and cost analysis showed it would not pay. For other sites the authority was blocked by town supervisors. According to one gentleman the supervisors were afraid of the political repercussions of permitting a landfill: "they wanted someone else - (e.g. the State Supreme Court) to tell them they had to cooperate and use the

land for a landfill. Then they could say they were forced to and not be responsible." The authority even considered purchasing a number of sites in different townships and using them on a rotating basis. Again local opposition was always too strong.

Consideration was given to constructing a compactor transfer station. This alternative failed for two reasons. First, the authority was unable to secure bonds unless they could guarantee the remote landfill would be around for the life of the transfer station. Second, West Chester would not commit itself to using the facility as this would be more costly than hauling to the privately owned Knickerbocker landfill.¹⁸

At the current time the WCJRDA operates no disposal facility. It has sold its equipment and the money is in the bank. It still owns the land where its landfills were situated and the value of the property is rising. In general the authority is still looking for sites but has few hopes for finding any. It is also waiting for the county solid waste management plan to be finalized so as to assess what is in store for the area.

Southeastern Chester County Refuse Authority (SECCRA)

The history of this authority begins in 1965-66. Kennett Square borough and Kennett township (hereafter KS and KT, respectively) began to study centralized landfills. KS had a foul dump and many complaints had been registered. KS and KT tried to involve other nearby municipalities but were unable to do so as these had some sort of disposal facility already and saw no need to change. Furthermore municipalities were reluctant to join an authority as they feared the landfill would be located in their own town.

At the same time that KS and KT were trying to organize an authority other municipalities around London Britain township were making similar efforts. A gentleman who helped to organize the London Britain area claims the stimulus there was state pressure. The state had recently become concerned with the dumps in that area and threatened to close them. This threat was coupled with local press reports and photographs of the conditions of the dumps. As a result nine to ten towns got together to participate in a "study group." These two groups - those around KT and those around London Britain - finally got together.

Meetings were held with town supervisors. "Hard sales talks were given." Movies (loaned by equipment companies) were shown. One person worked up a cost presentation showing that a cooperative arrangement would be a break-even proposition. The supervisors were impressed by this but were reluctant to form an authority. This reluctance was due to examples of other authorities which had made decisions without consulting involved persons. They were more interested in a private operation.

In about 1966 the study group found a farmer (with suitable land) who was willing to open his farm as a landfill and run it on their terms. In return all participating municipalities would agree (by resolution) to take all trash to him and to prevent other landfills from opening. However, word leaked out, citizens "descended" and the township supervisors caved in.

The study group continued to look for a site and hoped to find a buyer to run it properly. Finally the gentleman who was chairman of the board of supervisors of KT found over 60 acres for sale in KT. This gentleman - call him Mr. A - is a colorful figure and central to the organizing of the townships and boroughs. The 60 acres he found were ideally located in that they were sparsely settled. Only one residence is close to the site (across the street from it) but Mr. A - firmly committed to operating a truly sanitary landfill - convinced the persons in this residence to give it a try. Mr. A also convinced the other supervisors of KT and the towns' people to purchase the land, lease it to the authority and when filled turn it into a park.

Given KT's offer to have the landfill within its boundaries other municipalities were willing to go along and cooperate. The study group met, the land in KT was described and out of the group 10 municipalities decided to band together. There was still a question about whether to organize as an authority or not. Mr. A and Mr. B (the organizer in the London Britain area) believed that an authority was better than some form of contractual agreement. And, according to Mr. B, the selling point was that KT had the site so that other municipalities joined with the understanding that the landfill would not be within their corporate boundaries. However, to join the authority a municipality had to agree to two things. First, when the site in KT expired, township supervisors would not change the zoning ordinances within their jurisdiction. Second, townships would cooperate with the authority if their area would provide the best site for the next landfill.

For many of the townships that joined the SECCRA this agreement was harmless as they are located at some distance from the population center. Thus they are not likely to be candidates for the next landfill. Supervisors of the township which is the logical candidate for the next site were, at the time of the authority's inception, very sympathetic with the problem.

The Authority is composed of 10 municipalities - 7 townships and three boroughs. (Table 2 provides a list and description of these municipalities.) Each municipality contributed \$1/capita to the authority. In addition bank loans have been secured. The authority rents the land from KT for \$200/month and 7 $\frac{1}{2}$ % of its income. In addition, four other municipalities which did not join the Authority initially now have contracts to use it. These four contracting municipalities also paid \$1/capita. Members of the Authority and those with contracts have the right to bring refuse to the landfill. Payment for each load is charged on the basis of the size of the load.

Table 2

SECCRA: Population of Member Municipalities

Boroughs:	1970	1960	% Change
Kennett Square	4,876	4,355	12.0
Avondale	1,025	1,016	.9
West Grove	1,870	1,607	16.4
Townships:			
Kennett	3,394	3,026	12.2
Pennsburg	1,763	936	88.4
New Garden	4,153	3,718	11.7
London Grove	3,109	2,734	13.7
Penn	989	1,097	- 9.8
London Britain	963	686	40.4
Franklin	1,043	817	27.7

The landfill in KT has been in operation since 1968. The Authority has hired two men to run the operation. Mr. A, who resigned as supervisor of KT to assume the position of chairman of the authority, is a retired executive who, I gather, keeps a close watch on the operation. He is extremely concerned with keeping the landfill in top shape as he believes this will deter opposition to a future site. I met Mr. A at the site about 11 a.m. in August and received a "tour". Though I am not capable of judging the merits of the operation technologically I can say that it was not at all offensive. All refuse from the previous day had been covered. There was no odor and no flies were present. (Supposedly one rodent has been caught during the life of the landfill.) The entrance to the site was landscaped.

The person who lives in the house across the street is supposedly quite pleased with the operation and says he prefers having the landfill there to a housing development. He has also offered to speak to groups in other municipalities (if this should be necessary) where the next landfill would be located.

The landfill is run for the municipalities which are members of the Authority and those with contracts. However, it is hard to exclude other persons. Given its proximity to Delaware, persons with Delaware license plates do come up but are refused entry. All persons with Pennsylvania plates who "say" they are from a member (or contracting) municipality are permitted entry.

The Authority has been unable to get a license from the State, yet the State shows no signs of closing the site. Both men I interviewed feel there is no reason for not being licensed. One person attributes the difficulty in getting a license to a study done by a nearby university which found that the landfill produced leachate. Though all instrumentation installed since has shown no problems, the State is still reluctant to license the site. Those I interviewed felt that the site would remain unlicensed until it is closed in about 3 years.

The authority is currently looking for new sites. Since it does not wish "to go into the real estate business" it would prefer a rental arrangement such as it now has with KT. KT has practically recovered the price of the land it has been renting and this is being used as a selling point: "having a landfill is a way to get a 'free park'."

The Central Bucks Landfill Authority (CBLA)

The history of this authority (currently dissolved) begins in the mid 1950's. Given this time span, it has been most difficult to find persons who were involved with this effort. The history described here is largely based upon that given by a person who has been involved in local politics since the 1950's and participated in decisions regarding this authority.

Though the nature of the stimulus is unclear, efforts to form an authority were begun by an individual in Warrington township. A meeting was held in Warrington and the possibility of forming an authority, acquiring sites and quarries was discussed. Based upon this meeting the CBLA was formed and was composed of: Buckingham, Doylestown, Plumstead, Warwick, and Warrington townships and the boroughs of Doylestown, Chalfont and New Britain. (See Table 3 for population figures.)

Table 3

CBLA: Population of Member Municipalities

	1970	1960	% Change
Township:			
Buckingham	5,150	4,018	28.2
Doylestown	6,613	3,795	74.3
Plumstead	4,682	3,354	39.6
Warwick	2,138	1,810	18.1
Warrington	7,550	4,148	82.0
Boroughs:			
Doylestown	8,270	5,917	39.8
Chalfont	2,366	1,410	67.8
New Britain	2,428	1,109	118.9

During its lifetime the authority operated approximately four sites. The first (lasting for 2 years) was in Doylestown. Subsequently there were three sites in Buckingham: two quarry sites and one in lower land. None of these sites were well managed or resembled anything other than "dumps." The authority was most unwilling to spend money and tried to run the operations as inexpensively as possible, not realizing that larger expenditures would improve the operations.

To finance its operation the authority used a combination of assessments and users' fees. For capital expenses each municipality was assessed a "nominal fee" on a per capita basis. Operating expenses were defrayed by the fees paid by haulers. None of the municipalities involved had municipal collection and private haulers collected refuse. To insure that all trash collected from these municipalities would go to the authority's landfill, each municipality passed an ordinance requiring that all private haulers be licensed; licenses were, however, given only to persons who would use the authority's landfill.

Additional funds were gained by permitting "anyone" to use the landfill. Trenton, New Jersey and Montgomery County, Pennsylvania were regular users. Though this angered local citizens the policy was intended to make the landfill a self sustaining operation.

The demise of the authority began with complaints from citizens of Buckingham about the landfill in that township. As indicated previously the operation was quite poor - supposedly when a strong wind was blowing, paper and trash were scattered two to three miles. The citizen's annoyance provoked them to reorganize the Buckingham Civic Association - an older group which had become weak. This association began court action against the Authority to close the Buckingham site.

In response to this citizen action, a committee - composed mainly of elected supervisors from each member municipality - was formed to study the situation. For six months the committee met and, finally, it recommended that the authority disband. The reason for this recommendation was "not because there wasn't a need for the landfill but when the pressure was taken into account it seemed the best thing to do."

Thus, the authority was dissolved. Private landfills were used for a period of time. Then, when the state closed many of these, the county opened a landfill but this, too, was closed because of heavy leachate.

At the present time, private haulers take refuse to private landfills in lower Bucks. Though this is expensive, there are no plans to do anything about solid waste disposal. Apparently, the absence of municipal collection removes the burden of the expense of the current system from the political realm.

Perkasie - Sellersville - Quakertown

Perkasie, Sellersville and Quakertown (hereafter Perkasie, Sellersville and Quakertown) are three boroughs in Upper Bucks County which have, for over two years, been jointly studying the possibility of a new solid waste disposal facility. (See Table 4 for populations).

Table 4

Population of Perkasio, Sellersville and Quakertown

	<u>1970</u>	<u>1960</u>	<u>% Change</u>
Perkasie	5,451	4,650	17.2
Sellersville	2,829	2,497	13.3
Quakertown	7,276	6,305	15.4

All three boroughs have municipal collection and the impetus to consider new facilities came about when the landfill they had been using - Hidden Valley - was closed. Hidden Valley was a county operated landfill in a nearby township and was closed because of serious leachate problems. The county had purchased Hidden Valley (and planned improvements) to help municipalities in Upper Bucks. However, citizens in central and lower Bucks resented spending county money in this way. Furthermore, the county was reluctant to spend money without knowing that the facility would pay for itself and such assurance was not forthcoming.¹⁹ Hence, when Hidden Valley was closed, Perkasio, Sellersville and Quakertown were left with no disposal facility at all and were quite uncertain about the extent to which they could expect county aid. Thus, the need to plan for themselves arose.

Cooperation between Perkasio and Sellersville for solid waste management is a natural occurrence. Adjacent boroughs, there is a lengthy history of cooperation between the two. Though they do not have a joint refuse collection system they do share many parts of it: all ordinances regulating collection are identical in both boroughs and they aid each other when equipment breaks down. Thus when the waste disposal problem arose it was natural that the managers of both boroughs (who are good friends as well) attempted to solve the problem together. Though it is not adjacent, Quakertown is nearby and has municipal collection. Thus it seemed, to the managers of Perkasio and Sellersville, that Quakertown would also be interested in a new disposal arrangement.

Over two years ago, the elective councils of all three boroughs (over twenty-eight persons) got together. The three borough managers convinced the councilmen that some type of planning action was necessary. All councilmen agreed that this was important and that planning and study costs would be split three ways equally.

There are numerous other boroughs and townships in this area and it is most interesting that none of them were consulted about participating in this effort. The reasons for this - according to one gentleman - are as follows:

- (1) the other boroughs do not really provide services; they just hire persons when needed and, accordingly, it was presumed they would be uninterested in providing this service;

- (2) one borough is partly in another county;
- (3) townships are too rural and don't have the need and thus would be uninterested;
- (4) township supervisors are too "political;" and,
- (5) its hard to get so many people to agree.

Hence there was no attempt to include municipalities other than Perkasio, Sellersville, and Quakertown in the planning effort. At the same time, however, there was no intention to exclude these municipalities from using whatever facility was constructed; plans are to permit anyone who wishes to dump refuse for a fee.

Perkasie, Sellersville and Quakertown thus began a study of disposal facilities. At the time, most of the literature the managers read seemed to indicate that incineration was superior to landfill methods. Landfills were ruled out on other counts as well. The three boroughs are fairly heavily settled and none have enough space for a landfill. Hence they would have had to get land for a landfill from one of the nearby townships. But, due to the experience with Hidden Valley, there was much public sentiment against landfills. And, it was expected that the township supervisors would rapidly give in to public protest. In addition, townships could, by zoning, prevent land from being used as a landfill.

The study group did much work. It visited other incinerators and conducted its own study of solid waste production in the three boroughs. It concluded that an incinerator was a best solution. To construct an incinerator is, however, quite costly. Though financial aid was sought, none was available. Trips to Harrisburg and Washington turned up no funds at all. Hence, the borough managers seem to have concluded that it was too costly a solution: citizens in the boroughs would have had to pay approximately \$14/ton for disposal while others pay much less, and this seemed inequitable.

Despite the expense, the elected councilmen were in favor of constructing an incinerator and had reached a decision to build one in Quakertown. The borough managers, however, pointed out that the plan would be unfair to the citizens and thus convinced the councilmen not to go ahead.

At the current time there are plans to construct a transfer station which is perceived as a less expensive but also somewhat less satisfactory alternative. The only state licensed landfill in Bucks County is four hours round trip from Perkasio, Sellersville and Quakertown. Though it is out of the question, now, it would not be if a transfer station were available.

There is also talk of a private person constructing a transfer station or landfill in upper Bucks County in which case the three boroughs would be content to use it.

In any case, if neither the county nor a private person constructs a new disposal facility in upper Bucks County it seems likely that Perkasie, Sellersville and Quakertown will jointly build and operate a transfer station. One additional problem may arise. To receive a license for their facility it must be included in the County Solid Waste Plan (required by the State) which is eventually approved. Thus, officials in Perkasie, Sellersville and Quakertown are trying to convince the county planning commission to place this facility in the plan they are now drawing up.

Common Themes

An important goal of social science research is to develop valid general statements which serve to explain social phenomena. The goal of the research described here is to develop such statements to explain the inception and success or failure of cooperative efforts at solid waste disposal. To achieve such goals one between two research strategies. The first strategy involves consideration of a large number of municipalities; the second requires a consideration of a smaller number. To choose the first strategy is to limit the amount of information on each municipality but at the same time one's ability to generalize is increased. Choice of the second strategy means that one limits the number of cases analyzed but that a greater amount of information is gathered about each one. In areas where a priori knowledge is scarce it is most difficult to pursue the first strategy - i.e., in choosing to gather only a limited amount of information (about a large number of cases) it is possible to omit some of the more relevant factors. Hence, in situations such as this it would seem more worthwhile to conduct an in-depth investigation of a limited number of cases; to gather from these a few generalizations; and, to then test those on

a larger scale. Such is the strategy we have pursued in this project.

Though each of the four efforts at inter-municipal cooperation is unique in some ways, there are also some similarities. Identification of these similarities and dissimilarities should provide some "tentative" generalizations which would be worthy of exploration on a larger scale.

Municipal Collection and The Need for Disposal Facilities

It is somewhat improbable that municipalities with adequate long term disposal facilities would feel the need to participate in the creation of a new disposal facility. When the status quo is satisfactory no decision need be made. When, however, the status quo is unsatisfactory a municipality must consider activities to alleviate the problem.

In three of the four cases described here it is clear that (at least) the primary organizer of the cooperative venture had an acute need for changing the status quo. This need manifested itself along two dimensions. First, it became most difficult to continue to use the old sites. Kennett Square was receiving many complaints about its dump and other municipalities were receiving threats from the state to close theirs; West Chester's dump was inadequate; and, the poorly run county landfill used by Perkasie, Sellersville and Quakertown was closed by the State. Second, the need to actually do something was reinforced by the fact that each of these municipalities ran its own collection system.

This latter point - the presence of a municipally run collection system - is most important. Consider, for example, what happens in a municipality which does not run its own collection system. In this

situation collection would be handled by private haulers; when the landfill used by these persons is closed and they are forced to use a more distant one, costs rise and these costs are likely to be passed along to the consumer in higher rates for collection service. The consumer is not likely to enjoy this but local government remains uninvolved. In contrast, when the government itself collects refuse it alone would be the object of citizen annoyance.²⁰

Thus, in all but the Central Bucks case, it is clear that there was definite need to consider activities to change the status quo and, furthermore, this need was made even more acute by the presence of municipally run collection systems.²¹

Reasons for Cooperation

Even when a government is in need of a new facility it has a number of choices. It may provide it itself by either purchasing or leasing land within its boundaries or by purchasing or leasing land elsewhere. Or, it may join with other municipalities to provide landfill, incineration, etc. It is interesting, then, to consider the motivations to alleviate the problems through the formation of authorities or other intermunicipal agreements.

One reason for seeking cooperative agreements is due to an absence of appropriate land within the municipality that needs a new facility. West Chester borough, for example, had no available land for a landfill and had to look outside its boundaries. (In other cases it is possible that open space is available but is not geologically suited for a landfill). Municipalities lacking either available or suitable land must seek land in other municipalities.

It would seem that a best way to conduct this search is to enlist the aid of other nearby municipalities which do have land.

A second reason for seeking cooperative arrangements is to minimize the initial capital investment. Perkasio, Sellersville and Quakertown hoped to build an incinerator. Though this turned out to be too expensive even if costs were split three ways, it required a lower cash outlay from each municipality than if a single municipality had planned to construct it alone.

Thirdly, we are dealing here with small and almost rural municipalities on the periphery of a large metropolitan area. Each municipality, individually, produces a relatively small amount of waste. For each to operate a landfill is, to some extent, an underutilization of resources. That is, one landfill or incinerator can serve a number of towns such as those described here. Intermunicipal cooperation is, then, a way to make efficient use of land, machines and manpower.

The Politics of Personality

At the end of one interview I was told:

Nobody understands local government. To get cooperation you need one person - an influential and respected member of the community. Other people will do things and cooperate if he asks them to.

You need people who are dedicated and will spend the time needed to run the place. There aren't enough people around who have the time and know what they are doing. Local government depends upon such people!

Certainly personality has played a positive role in at least two of the cases described in this paper. The person referred to as Mr. A., who helped organize and run the SECCRA is just such a person as is described above. A wealthy executive whose hobby is local government Mr. A. has been most influential. He is truly dedicated to operating a sanitary landfill. Mr. A. is now retired and admitted that the availability of his time is one reason the authority's landfill has worked so well. Though two men are hired to run the site he can oversee their operation. Since he also knows what should be done he is a valuable overseer.

The cooperation between Perkasis, Sellersville and Quakertown may also be due in part to personality. One of the borough managers struck me as a dynamic person who would work hard for a "best" arrangement. It appears that he coordinated all of the cooperation which has occurred and is a truly influential and concerned leader.

The personal friendship (the extent of which I cannot describe) of two borough managers must also be considered as an element of "personality politics." For certainly this friendship made cooperation a bit simpler than it otherwise would be.²²

Citizen Protest

The failure of municipalities to form and operate cooperative disposal facilities is most easily attributed to citizen protest activity or, the perceived threat of it. The most frequently heard statement is that "nobody wants a landfill in his backyard." Thus, the unaesthetic nature of solid waste disposal creates one of the largest obstacles to a satisfactory solution.

As examples of this, the failures of both the CBLA and the WCJRDA seem to have been caused by citizen discontent. In the CBLA, no attempt was made to find a new site or to improve the operation of the old one. Rather a recommendation to disband the Authority was followed. The WCJRDA has not dissolved but the likelihood of citizen protest has forced it to remain inactive. Politicians in towns with suitable land have refused to permit landfills to be placed therein. Clearly they fear citizen discontent and the consequent political costs of granting permission.

The SECCRA represents an interesting case in this regard. Their first attempt to find a site did fail because of citizen protest. A new site of over 60 acres (where the landfill is currently) was found by Mr. A. who convinced Kennett Township to purchase it and lease it to an authority. To be used as a landfill rezoning was necessary. However, to keep everything above board this was carried out publicly and was completely in the open. Since the site is close to only one residence there was an objection only from this one person who was convinced to "wait and see." Once it was known that the landfill would be in Kennett other municipalities were of course willing to join the authority.²³

The SECCRA is currently looking for a new site. And, it remains to be seen whether the authority continues after the current site is closed and when some other municipality must permit a landfill within its territory. Kennett has found that, through its rental arrangement, it has recovered the price of the land and it intends to create a park on the site. Thus, other towns are being told that this is a way to get a free park.

The future success of the SECCRA will be interesting to watch for another important reason. Few citizens have had experience with a landfill that is well run as is the one run by the SECCRA. When citizens think of a landfill it is highly likely they think of a "dump." However, the plans of the SECCRA were to run their first site in a sanitary fashion to give citizens a "good" image of landfills and minimize future opposition. It remains to be seen whether this strategy succeeds. If, however, it does then we have learned an interesting fact; citizens will accept well run landfills and their current opposition is due largely to a belief that all landfills are dumps.

IV A Game-Theoretic Analysis of Intermunicipal Agreements for Solid Waste Disposal

In the previous section I described the histories of four specific efforts at intermunicipal cooperation. These case studies demonstrate that there are numerous stumbling blocks to successful cooperation.

In this section of this paper I turn to a formal and more general analysis of the decision to cooperate with other municipalities. I assume that municipalities behave as rational actors; they choose to cooperate (or not) if the resulting outcome has the highest payoff. By specifying the parameters of the choice situation one is able to identify the choices which such rational actors would make. In so doing one can discover whether the choice situation provides a rational actor with any incentives to cooperate.

The primary goal of this analysis is to utilize a formal theory to explain the outcomes described in the previous section as well as general lack of intermunicipal cooperation. Nevertheless, I must point out that the work described here is perceived as only a "first-step" in this direction. Accordingly, the choice situation I dealt with here is simpler than the real one.

To begin, I consider in this analysis the decisions of only two municipalities. I assume there are two municipalities "a" and "b", and that each can choose from two alternatives: to "cooperate" with the other or to "not cooperate" with the other.²⁴ Four possible outcomes can occur, and each outcome provides a specific payoff to each player (in this case, a municipality). The general choice situation is illustrated in Matrix 1.

Matrix 1

Municipality "a"

		Cooperate (c)	Not Cooperate ($\bar{c}$)
Municipality "b"	c	O_1 $B_b - C/2 - p_b X_b, B_a - C/2 - p_a X_a$	O_2 $B_b - C - X_b, B_a$
	$\bar{c}$	O_3 $B_b, B_a - C - X_a$	O_4 $0, 0$

B_a, B_b = the benefits of a new disposal facility to a and b, respectively;

C = the total monetary costs of starting a new facility;

X_a, X_b = the political costs of starting a new facility to a and b, respectively;

p_a, p_b = the probability of incurring X_a and X_b .

Payoffs are simply a matter of the benefits accruing to each outcome minus its costs and the following reasoning has led to the specification of payoffs found in Matrix 1.

When both municipalities choose not to cooperate, outcome 4 (denoted as O_4) results. It is assumed that each municipality has decided to maintain the status quo and to continue to dispose of waste in the currently used fashion. Though the status quo may, in absolute terms, produce a negative payoff, we have chosen to associate the payoff of zero with this outcome. The desirability of other outcomes is thus determined by whether or not the associated payoffs are greater or less than zero.

When both municipalities decide to cooperate to provide a disposal facility, O_1 results. Each receives certain benefits but must also incur certain costs. In general we assume that, costs aside, the new facility will represent an improvement over the status quo. That is:

$$B_s \geq 0, s = a, b. \quad 25$$

Benefits may take a number of forms. If the new facility is less distant than that which is currently used, hauling costs will be reduced. A new facility with large volume may further reduce disposal costs per se, by capturing economies of scale. If the currently used method of disposal is inadequate in that it pollutes ground water, attracts rodents, or creates a fire hazard, a new and more adequate facility will produce benefits of health and happiness.

Turning to costs, two sorts are likely to be involved: monetary and political. In the cases we have studied, cooperating municipalities

contributed, at the outset, a sum of money for initial expenses such as purchase of land and/or equipment. (Operating costs were defrayed by users' fees). C , then, is the amount of capital needed to start a new facility and it is assumed that:

$$C > 0$$

When municipalities cooperate it is common that they share their monetary costs. For simplicity we have assumed they are shared equally and that $C/2$ is the cost each of two municipalities must pay.

Political costs arise from citizen discontent over the location of a waste disposal facility in their "backyards." If a local politician permits a landfill to be placed within the corporate boundaries of his municipality, he risks the ire of his electors and a possible defeat at election time. The case histories we have gathered provide ample evidence that these political costs loom large in the minds of local politicians. Thus we assume:

$$X_s > 0, s = a, b$$

However, when two municipalities decide to provide a single facility there is only a chance of incurring these costs. This chance is denoted by p_a and p_b . These are the probabilities of the facility being located in municipality "a" or "b". Since the choice of a site depends upon numerous factors - available land, suitable terrain, road access, centrality of location, etc. - which may be unequally distributed between "a" and "b", it is possible that p_a is greater than p_b or vice versa. In general it is assumed that:

$$p_s > 0, s = a, b$$

$$p_a + p_b = 1$$

Thus, if both "a" and "b" decide to cooperate each can expect to receive certain benefits, to contribute a certain amount of money and to risk incurring political costs.

O_2 or O_3 results when one municipality chooses to "cooperate" but the other chooses not to. By this I mean that the cooperating municipality alone chooses to provide a new disposal facility. O_2 results when "b" cooperates and "a" does not: I assume that "b" receives the same benefits as if O_1 occurred but, since "a" does not cooperate here, "b" must incur all the political and monetary costs. At the same time I assume that the non-cooperating municipality, "a", receives the benefits of a new facility but incurs no costs whatsoever. These assumptions are based upon the previously described case studies. In each of these cases disposal facilities were open to any paying person (or hauler). In some instances this was a matter of policy²⁶; in other instances it was because the costs of excluding "non-cooperators" were perceived to be too high.

Examination of Matrix 1 clearly demonstrates that some outcomes result in higher payoffs for "a" or "b". Since "a" and "b" are assumed to be interested in receiving the greatest payoff, it is possible to describe their preference ordering for outcomes. Since $B_a > 0$, "a" prefers O_2 to O_4 . Similarly, $B_a > B_a - C/2 - p_a X_a > B_a - C - X_a$. Hence, for "a", $O_2 \succ O_1 \succ O_3$ (O_2 is preferred to O_1 is preferred to O_3). The assumptions about payoffs do not, however, define "a's" preferences between O_4 and O_1 or O_3 .

In general "a" could have any one of three possible preference orderings:

$$a_1: B_a > B_a - C/2 - p_a X_a > B_a - C - X_a > 0$$

$$\Rightarrow O_2 P O_1 P O_3 P O_4$$

$$a_2: B_a > B_a - C/2 - p_a X_a > 0 > B_a - C - X_a$$

$$\Rightarrow O_2 P O_1 P O_4 P O_3$$

$$a_3: B_a > 0 > B_a - C/2 - p_a X_a > B_a - C - X_a$$

$$\Rightarrow O_2 P O_4 P O_1 P O_3$$

There are three similar orderings for municipality b:

$$b_1: B_b > B_b - C/2 - p_b X_b > B_b - C - X_b > 0$$

$$\Rightarrow O_3 P O_1 P O_2 P O_4$$

$$b_2: B_b > B_b - C/2 - p_b X_b > 0 > B_b - C - X_b$$

$$\Rightarrow O_3 P O_1 P O_4 P O_2$$

$$b_3: B_b > 0 > B_b - C/2 - p_b X_b > B_b - C - X_b$$

$$\Rightarrow O_3 P O_4 P O_1 P O_2$$

Since each municipality may order the outcomes of the matrix in one of three ways, there are nine distinct cases. Thus, Matrix 1 (together with our assumption) describes nine possible games; which of these is being played depends, of course, upon "a's" and "b's" ordering of the outcomes. For the sake of clarity $a_j b_k$ will denote the situation where "a" has preference ordering a_j and "b" has preference ordering b_k , ($j, k = 1, 2, 3$) as listed above. Hence game $a_1 b_1$ is the game described in the matrix where "a" orders the outcomes as in a_1 ($O_2 P O_1 P O_3 P O_4$) and "b" orders the outcomes as in b_1 ($O_3 P O_1 P O_2 P O_4$).

The nine possible games may be divided into two classes: those which are quasi symmetric (q-s) and those which are non-symmetric (n-s).

The q-s games are the three games $a_j b_k$ for which $j=k$; the n-s games are those six games $a_j b_k$ for which $j \neq k$.

The reasons for distinguishing these two classes is most important. The q-s games describe situations where both "a" and "b" have a similar perception of the world. They order outcomes in the same way. Thus, in $a_1 b_1$, both "a" and "b" perceive maintenance of the status quo to be the worst outcome: each municipality finds it more worthwhile to provide its own disposal facility and incur total costs than to continue the status quo (i.e. for "a," $O_3 \succ O_4$; for "b," $O_2 \succ O_4$). In general one can view the q-s games as those where the relative merits of different outcomes are the same for both players.

In the n-s games there can be great dissimilarity in the players' perception of the world. Consider, for example, $a_1 b_3$. In this game, "a" perceives the status quo to be the least desirable outcome. "b", however, is not as unhappy with the status quo and, in fact, evaluates it second only to O_3 . It is possible to interpret "a's" situation as being more desperate than "b's". In this game "b" has no incentive whatsoever to cooperate while "a" does have some reason to do so.

It should be apparent that any of these nine games can occur in reality. A municipality's ordering of outcomes will naturally depend upon whether it perceives current disposal arrangements to be very poor, merely unsatisfactory or adequate.

Let us turn now to an analysis of the choices that rational players would make in each of these nine games.

Game $a_1 b_1$. In this game municipalities "a" and "b" have the following preferences over outcomes:

a: $O_2 \succ O_1 \succ O_3 \succ O_4$

b: $O_3 \succ O_1 \succ O_2 \succ O_4$

1' 2 2	2' 1 3
3' 3 1	4' 4 4

(In the accompanying diagram "a's" ordering is on the top). Clearly, neither "a" nor "b" has a "dominant pure strategy. That is, neither c nor $\bar{c}$ is best against all choices by the other player. When, for example, "b" chooses the cooperative strategy c , "a" does best when it chooses $\bar{c}$; on the other hand if "b" chooses $\bar{c}$, "a" is best off choosing c .

If there is no single best choice how can we expect players to behave? One answer to this question asserts that rational players should choose a maximin strategy. That is, one should act to maximize the minimum payoff he could expect to receive. In the case under consideration, the choice of c is the maximin choice for each player. By choosing c each can guarantee himself a payoff of, at least, $B - C - X$. (Hereafter we will delete the subscript where the payoff described refers to both players - i.e. in this context a insures himself $B_a - C - X_a$; b insures himself $B_b - C - X_b$). And each precludes the possibility of a payoff of zero.

If each player behaves in this fashion, the outcome is the cooperative one, O_1 . But certainly this is not a stable outcome since each player is tempted to "defect" - to choose $\bar{c}$ - and reap still greater returns. In game theoretic terms O_1 is not an "equilibrium" outcome as at least one player can improve his situation by shifting his strategy.

Some maintain that we could not expect an outcome other than one which is in equilibrium.²⁷ And, there are two equilibrium outcomes - O_2 and O_3 . If either of these is reached, neither player can increase his payoff by individually changing his behavior.

In the perfectly symmetric games, Rapoport and Chammah argue that O_2 and O_3 would be unacceptable as they are themselves unsymmetric and

favor one of the two players. However, in the situation we have described, where the inadequacy of current disposal methods and thus the willingness to bear costs are not assumed identical, such outcomes may be more reasonable. Player A may argue: "The status quo is much worse for you than for me (i.e. $B_a < B_b$). Hence I can better afford to continue the present arrangement and you should be the one to build a disposal facility." If "b" realizes the asymmetry of the situation he may respond by choosing c in response to "a's" $\bar{c}$ and the result will be O_2 . But it is also possible that "b" would respond to "a" by "threatening" to choose $\bar{c}$ if "a" chooses $\bar{c}$. The resulting outcome would be the status quo - O_4 . Once more, "a" is placed in the original dilemma: if he believes "b" will choose $\bar{c}$ he ought to choose c; if he does not believe this he is best off choosing $\bar{c}$.

In short, it seems one can rationalize the occurrence of any of the four outcomes in $a_1 b_1$. If maximin strategies are chosen, cooperation will result. As was pointed out, however, the payoff structure provides a temptation for each municipality to depart from its cooperative choice.

Game $a_2 b_2$. In this game the following preferences over outcomes are held:

a: $O_2 P O_1 P O_4 P O_3$

b: $O_3 P O_1 P O_4 P O_2$

1 2 2	2 1 4
3 4 1	4 3 3

Though each municipality would find it worthwhile to cooperate to provide a facility ($B - c/2 - pX > 0$) neither perceives it is worthwhile to provide the facility alone and bear total costs ($B - c - X < 0$). Each prefers the status quo to individual provision. This game may be interpreted as depicting a situation in which current disposal facilities are somewhat more adequate than those existing in the game $a_1 b_1$.

The game a_2b_2 is the very common and often discussed Prisoners' Dilemma Game (PDG). For each player $\bar{c}$ is a dominant pure strategy; regardless of what the opponent does $\bar{c}$ yields the highest payoff. The result, though, is a suboptimal outcome; both players would be individually better off if each chose c . Hence, the dilemma of the situation: individual maximizing behavior produces a suboptimal outcome.

The PDG is usually treated as a non-cooperative game - communication between players is not permitted. And in the absence of communication it is clear that $\bar{c}$ is one's best bet. If communication is possible (as it is between municipalities) it is often said that players will coordinate their behavior: each will choose c and a more desirable outcome will be reached. But (and there always are "buts" when discussing non-zero-sum games) it is still unilaterally advantageous for each actor to defect and to back out of a cooperative arrangement before implemented. Thus, unless commitments to cooperate are enforceable one may logically expect any individual to choose non-cooperation.

Game a_3b_3 . The preferences of "a" and "b" are:

a: 0 P 0 P 0 P 0
 2 4 1 3
 b: 0 P 0 P 0 P 0
 3 4 1 2

1/ 3	2/ 1
3/ 3	4/ 4
3/ 4	4/ 2
1/ 1	2/ 2

If this situation occurs, there is a dominant pure strategy for each player and no "dilemma" whatsoever. The choice of $\bar{c}$ is best for both "a" and "b;" it results in O_4 - maintenance of the status quo - which is a Pareto optimal, equilibrium outcome. Though O_4 is, for both "a" and "b," the second most preferred outcome, there is no temptation to adopt cooperative behavior. Doing so would result in the third most preferred outcome rather than the first.

The three quasi-symmetric games, just outlined, describe somewhat different states of the world. These states reflect the inadequacy of current disposal facilities and consequently, the willingness of a municipality to bear the total or partial costs of a new facility.²⁹ In a_1b_1 the situation is quite bleak: both municipalities perceive the status quo to be the worst outcome and each would prefer any other outcome to this. In a_2b_2 the status quo is perceived as more desirable than individual provision of a new facility, indicating that the status quo is seen to be less inadequate than in a_1b_1 . In a_3b_3 the status quo is preferred to even the outcome involving joint provision and a sharing of costs. Hence as one moves from a_1b_1 to a_3b_3 the status quo becomes less threatening relative to other alternatives.

With respect to behavioral expectations, one may note that the status quo is likely to be maintained in both a_2b_2 and a_3b_3 . In a_3b_3 this is a logical outcome given the preferences of individual actors. In a_2b_2 this presents us with a dilemma: there is another Pareto optimal outcome which is unlikely to be reached. In a_1b_1 , where the status quo is perceived as the least desirable outcome, there is still reason to believe it may result. In this situation cooperation will occur only when actors choose maximin strategies which, as was discussed previously, are less advantageous than other forms of behavior. Hence even in the a_1b_1 situation the cooperative outcome is not a sure thing.

Turning to the non-symmetric games, there are six of them and they are:

a_1b_2 and a_2b_1

a_1b_3 and a_3b_1

a_2b_3 and a_3b_2

Since $a_j b_k$ and $a_k b_j$ are conceptually the same except for the labelling of the actors, only three of these require analysis.

Game $a_1 b_2$. In this situation the preferences of "a" and "b" are as follows:

a: $O_2 P O_1 P O_3 P O_4$

b: $O_3 P O_1 P O_4 P O_2$

1/ 2	2/ 1
2	4
3/ 3	4/ 4
1	3

For "a" the status quo is the least preferred outcome. For "b" it is more preferred than individual provision of a new facility - O_2 . A number of interpretations are possible. For example, "a" might be a rapidly growing municipality with a landfill that will soon be forced to close. "b" might be a municipality which is not experiencing such rapid growth so that its current landfill can be expected to last for a number of years. "a", thus, must do something quickly; "b" is not so desperate but realizes the advantages of an additional facility and would, in fact, find it worthwhile to share the costs of such. Thus it may be that $B_b < B_a$ and, $B_b - C - X_b < 0$ while $B_a - C - X_a > 0$. Alternatively, political pressures could be greater in "b" than in "a" so that $X_b > X_a$. Again, the two inequalities are possible.

In this situation, "b" - the less desperate municipality - has no incentive to cooperate: $\bar{c}$ is a dominant choice and best regardless of "a's" behavior. If b is expected to choose $\bar{c}$, then "a" should choose c as $B_a - C - X_a > 0$. Hence, if this situation occurs we could expect "a" to alone provide a new facility and "b" will reap any benefits "free of charge."

Game $a_1 b_3$. As in the above situation "a" is somewhat desperate and would prefer any outcome to the status quo. "b," however, does not even

perceive it to be worthwhile to share the costs of a new facility.

"b's" preferences are

$$b: O_3 P O_4 P O_1 P O_2$$

Accordingly $\bar{c}$ is again a dominant strategy for "b," and "a" is best off choosing c if "b" chooses $\bar{c}$. As in the preceding situation one would expect "a" to provide a new facility alone.

Game a b The preferences of "a" and "b" are:
 2 3

$$a: O_2 P O_1 P O_4 P O_3$$

$$b: O_3 P O_4 P O_1 P O_2$$

1	2	2	1
	3		4
3	4	4	3
	1		2

As in the preceding case, a choice of $\bar{c}$ is best for "b". Since "a" prefers O_4 to O_3 $\bar{c}$ is also best for "a". Hence, we could expect the status quo to continue.

A summary of expected outcomes for each of the nine games is given in Table 5.

Table 5
Expected Outcomes in Nine Games

Game	Outcome	Description of Outcome
a ₁ b ₁	Undetermined	
a ₂ b ₂	O ₄	no cooperation
a ₃ b ₃	O ₄	no cooperation
a ₁ b ₂	O ₃	individual provision by "a"
a ₁ b ₃	O ₃	individual provision by "a"
a ₂ b ₁	O ₂	individual provision by "b"
a ₂ b ₃	O ₄	no cooperation
a ₃ b ₁	O ₂	individual provision by "b"
a ₃ b ₂	O ₄	no cooperation

This table shows that cooperative outcomes are unlikely. In only one of the nine games (a_1b_1) is a cooperative outcome possible - and even here there is no reason to expect it to result. In the remaining eight games, rational choice leads away from the cooperative outcome.³⁰

Of course, one must realize that in some of these games the cooperative outcome is not "socially" desirable. In the game a_3b_3 , for example, each municipality prefers the status quo to the cooperative outcome. And, in general, when preference orderings a_3 or b_3 hold, this indicates the municipality sees no benefits accruing to change. However, in four of the games described -- a_1b_1 , a_2b_2 , a_1b_2 , a_2b_1 --both municipalities prefer the cooperative outcome to the status quo. Nevertheless, cooperation is still unlikely to result.

The previous section of this paper described four efforts at intermunicipal cooperation for waste disposal. In each of these cases there were numerous difficulties and in two cases these led to failure of the cooperative effort. The analysis of this section shows that these difficulties are not unique to the situations described. Nor are they trivial problems of the personalities involved. Rather, the stumbling blocks to cooperation are rooted in the more general choice situation. Given the parameters of choice, rational actors simply have no incentive to cooperate, and this is true even when the cooperative outcome is preferred to the status quo.

Concerning the WCJRDA and CBLA efforts, political costs were perceived to be extraordinarily high. One could infer from this that all involved municipalities in these cases had preference

orderings similar to a_3 . In other words, the game a_3b_3 probably describes these two cases and the logical outcome is that which arose -- no cooperation.

The Parkasie - Sellersville - Quakertown case is somewhat different. The status quo (represented as O_4) was perceived to be intolerable and was probably the least preferred outcome for the three municipalities. The most preferred outcome would have been to have someone else (another municipality, the county or a private operator) provide disposal. Provision of disposal either cooperatively or individually probably ranked, respectively, second and third in preference orderings. Hence, the game a_1b_1 was played. From our analysis of this game any outcome is possible including the cooperative one. It must, however, be noted that no final agreement has been reached by these three municipalities. This may be due to the confusion inherent in the situation and the lack of a clearly rational choice.

The SECCRA case is more difficult to explain in game theoretic terms. It is most likely that game a_2b_2 - the PDG game - applies here but with one qualification. When KT offered to have the landfill within its own territory, the difference in payoffs between the most and second most preferred outcomes was sharply reduced. That is, the most preferred outcome is where someone else provides disposal and the municipality incurs neither political nor capital costs; the payoff is B. The second most preferred outcome is the cooperative one where the typical payoff is $B-C/2 - pX$. In the SECCRA case, however, p was made zero for all municipalities other than KT so that the payoff from cooperation was $B-C/2$. Since monetary requirements were very low this suggests that municipalities may have been

close to indifferent between their most and second most preferred outcomes. If indifference does hold then the preferences (for two of the municipalities) are as follows: (where a's ranking

		C	$\tilde{C}$
		1	2
C		1 1	1 3
$\tilde{C}$		3 3 1	4 2 2

of an outcome is on top in each cell): $\tilde{C}$ remains a dominant choice. But this is where "personality" enters. The organizers of SECCRA apparently convinced other individuals that C would be a better choice and would lead to a more preferred outcome. Furthermore, in this modified game, there is no reason to choose $\tilde{C}$ when other municipalities choose C since municipalities are indifferent between the two resulting outcomes. Hence in SECCRA's case, the original PDG was modified by KT's willingness to provide space for the landfill. The persons who organized this Authority served, additionally, to point out the true dimensions of the situation to others who were initially reluctant to join us.

For cooperative outcomes to result, and clearly this is not always desirable, the choice situation must be restructured so that there is an appropriate incentive to cooperate. One important modification is to make all disposal facilities exclusionary -- open only to cooperating municipalities.

Cards or other symbols of identification should be issued to those permitted to use the facility.³¹ Though this is a rather simple suggestion it removes a major problem. Nevertheless, it may

not be easily accepted. If the facility is not used by a large population, operating costs will be higher. Thus, expected benefits will be lower for cooperating municipalities. However, if non-cooperating municipalities anticipate no benefits whatsoever (they are excluded) they will be more likely to participate.

The payoff structure resulting from such a policy is depicted in the following matrix:

Matrix II
"a"

		c	
		1	2
"b"	c	$B_b - C/2 - p_b X_b, B_a - C/2 - p_a X_a$	$B_b - C - X_b, 0$
	$\bar{c}$	$0, B'_a - C - X_a$	$0, 0$

where: $B_a, B_b, X_a, X_b, p_a, p_b$ are as defined in Matrix I

B'_b, B'_a are the reduced benefits of individually providing a facility when others are excluded.

In this case "a" still prefers O_1 to O_3 . But "a" is now indifferent between O_2 and O_4 . If "a's" preference ordering was a_1 --

$O_2 P O_1 P O_3 P O_4$ -- then when the payoff from O_2 is reduced to zero, his new preference ordering will be a'_1 :

$O_1 P O_3 P O_4 I O_2$. (I stands for indifference). Similarly, preference ordering a_2 and a_3 become:

$a'_2 : O_1 P O_4 I O_2 P O_3$

$a'_3 : O_2 I O_4 P O_1 P O_3$

And, for b one has:

$$b_1' : 0_1 P 0_2 P 0_3 I 0_4$$

$$b_2' : 0_1 P 0_4 I 0_3 P 0_2$$

$$b_3' : 0_3 I 0_4 P 0_1 P 0_2.$$

The outcomes for the nine new games are described in Table 6.

Table 6

<u>Game</u>	<u>Outcome</u>	<u>Description of Outcome</u>
$a_1' b_1'$	0_1	cooperative
$a_2' b_2'$	0_1	cooperative
$a_3' b_3'$	0_4	non-cooperative
$a_1' b_2'$	0_1	cooperative
$a_2' b_1'$	0_1	cooperative
$a_2' b_3'$	0_4	non-cooperative
$a_3' b_2'$	0_4	non-cooperative
$a_1' b_3'$	0_3	individual provision by a
$b_1' a_3'$	0_2	individual provision by b

One should note that in all four games where both municipalities prefer the cooperative outcome to the status quo, the cooperative outcome results! The status quo is maintained only when it is the most preferred outcome for one or both municipalities (i.e. $a_3' b_3'$, $a_2' b_3'$, $a_3' b_2'$). Individual provision results only when one municipality prefers the status quo to all other outcomes (ordering a_3' or b_3') and the other municipality prefers individual provision to the status quo (ordering a_1' or b_1').

A policy of exclusiveness by those planning cooperative enterprises results in a reasonable set of outcomes given different preferences. It removes the disincentive to cooperate when such cooperation is desirable. In contrast a policy of non-exclusion, such as that adopted by most municipalities, tends to inhibit cooperation. Thus non-exclusion makes it rational for individual municipalities to make non-cooperative choices. The end result is the occurrence of some socially bizarre outcomes.

FOOTNOTES

¹ See, for example: Robert Wood, 1400 Governments (Harvard University Press, 1961); Reinhold P. Wolf, "The Curse of Multiplicity," in Philip B. Coulter, ed., Politics of Metropolitan Areas (Thomas Crowell 1967); The Advisory Commission on Intergovernmental Relations, The Problem of Special Districts in American Government (ACIR, 1964).

² See, for example, Edward C. Banfield and Morton Grodzins, "The Desirable and the Possible;" and, Luther Gulick, "Needed a New Layer of Local Government," both in Edward C. Banfield, ed. Urban Government (The Free Press, 1969), Reshaping Government in Metropolitan Areas (Committee for Economic Development, 1970); Vincent Ostrom, Charles Tiebout and Robert Warren, "The Organization of Government in Metropolitan Areas, A Theoretical Inquiry," American Political Science Review, 55 (Dec. 1961); Daniel R. Grant, "Urban Needs and State Response: Local Government Reorganization," in Alan Campbell, ed., The States and the Urban Crisis (Prentice Hall, 1970); Lowdon Wingo, ed., Reform of Metropolitan Governments (Resources for the Future, Inc., 1972); Robert L. Bish, The Public Economy of Metropolitan Areas (Markham, 1971, especially chapter 3).

³ Much of the literature on scale economies as well as its problems is summarized in Werner F. Hirsch, "The Supply of Urban Public Services," in Harvey S. Perloff and Lowdon Wingo, Jr., eds., Issues in Urban Economics (Johns Hopkins, 1968).

⁴ Robert Bish contends that "under many conditions, the economies of scale realized in production are irrelevant to determining the optimum size of a political unit; this is because there is no necessity for the same political unit both to articulate demand for a public good and to produce its supply," op. cit., p. 54. Others have argued that there is little evidence that significant economies of scale can be realized for a large number of services. See, Steven P. Erie, John J. Kirlin, and Francine F. Rabinovitz, "Can Something be Done? Propositions on the Performance of Metropolitan Institutions," in Wingo, ed., op. cit. pp. 22-24.

⁵ See, Alan Williams, "The Optimal Provision of Public Goods in a System of Local Governments," Journal of Political Economy, (Feb., 1966).

⁶ Op. Cit.

⁷ Op. Cit., p.

- ⁸For a discussion of these and other formal and informal coordinating devices, see: John C. Bollens, Henry Schmandt, et. al., Exploring the Metropolitan Community (U. of Calif., (1961), pp. 70-86.
- ⁹John C. Bollens, Special District Governments in the United States (U. of Calif., (1961), pp. 2-4.
- ¹⁰(October, 1962), p. 22.
- ¹¹Advisory Commission on Intergovernmental Relations, Performance of Urban Functions: Local and Area-wide (Sept., 1963).
- ¹²Of course, these "diseconomies" can be reduced by installing transfer stations so that no single municipality is forced to haul waste any great distance.
- ¹³If a county or regional government provides a number of facilities it can reduce the increased hauling costs associated with a single centralized facility for a large area. To argue that a county or regional unit is inappropriate one may hark back to the fact that large governments do stifle freedom of choice. It is conceivable that some persons would prefer to live near a landfill than to pay for an elaborate recycling plant and vice versa. If regional units make decisions, all persons are forced to adhere to a single standard where this may not be necessary. For a related discussion on the benefits of small and homogeneous political units see, Bish, op. cit., pp. 45-53.
- ¹⁴Each description is based upon interviews conducted with knowledgeable persons during the summer and fall of 1972.
- ¹⁵All persons contacted said this was the case. Yet none of them were present when the authority was first created. Furthermore I could not contact anyone who was present when it was started.
- ¹⁶Two of the persons I spoke with said there had been two sites in West Goshen. Hence I assume the description of "the landfill" refers to both of these which were run successively by the authority.
- ¹⁷Since the authority considered a large number of sites it could be that these two versions refer to two different sites in East Bradford and that each interviewee was describing only one of these.
- ¹⁸The transfer station would have cost about \$6/ton; Knickerbacher costs about \$4.50/ton. Since West Chester is the largest producer of waste, the construction of a transfer station for only the remainder of the authority would have been unwarranted.

- 20 One might conjecture that in cities and towns without their own collection, collection is seen to be a service of the private market so that when collection becomes poor (or too expensive) citizens do not even think of government as responsible. In cities where there is municipal collection it is likely that this service is perceived to be within the legitimate sphere of government activity. Hence, in the latter case collection problems are the responsibility of government.
- 21 In the CBLA, I was told that they needed a landfill, yet it is not clear why this need was so acute.
- 22 Similar findings about the importance of personality are reported in John E. Stoner, Interlocal Cooperation: A Study of Five States, Agriculture Economic Report #118 (U.S. Dept. of Agriculture, Economic Research Service; Wash., D.C., July, 1967).
- 23 A few municipalities, however, did not join as they believed their current arrangements to be satisfactory. Many of these now have contracts with the authority.
- 24 In reality, of course, there are usually more than two municipalities involved. Moreover there are a wide variety of alternatives from which to choose e.g. "cooperate with municipality a or b or c or a and b", etc.; "cooperate to provide a landfill, an incinerator", etc. In reducing the choice structure to a two-person two-choice context, I am well aware that I am omitting many important aspects of the real choice process. Nevertheless, I believe that this simplification does capture some of the intricacies of the real process and as such can provide useful information.
- 25 If $B_s < 0$, then there is no reason for a municipality to even consider changes in the status quo. Hence this paper pertains only to cases where, costs aside, it is possible to improve waste disposal; where $B_s < 0$, the logical outcome is no cooperation.
- 26 See the description of the CBLA in Section III.
- 27 Those conversant with game theory will realize we are exploring various solutions to the game at hand and encountering the usual difficulties inherent in solutions to non-zero-sum games. For others we note that a solution is a description of outcomes we could expect if all players were to behave rationally - so as to maximize their payoffs. Solutions to non-zero-sum games have been characterized in many ways - i.e. outcomes resulting from maximin choices, outcomes that are in equilibrium, outcomes that are pareto-optimal, etc. Unfortunately, each definition of a solution is unsatisfactory in one or more ways so that in the absence of a dominant pure strategy one is unable to identify behavior which would be commonly perceived

- ¹⁹ The county asked individual municipalities to pass ordinances guaranteeing wastes would go to the county site. However, none of the townships would do this. One reason is that townships are very rural, have no municipal collection and therefore would have a hard time enforcing the law. Moreover, there is some evidence of hostilities between county and local officials so that local officials did not wish to go along with the county.
- to be best. See R. Duncan Luce and Howard Raiffa, Games and Decisions (John Wiley, 1957), ch. V.
- ²⁸ Anatol Rapoport and Albert M. Chammah, "The Game of Chicken" in Ira R. Buchler and Hugo G. Nutini; eds. Game Theory in the Behavioral Sciences (U. of Pittsburgh Press, 1969), p. 152. The game a_1b_1 is identical in its ordering of outcomes to the game of "chicken." Chicken is usually described as symmetric. Here, that would mean that: $B_a = B_b$, $X_a = X_b$, $P_a = P_b$.
- ²⁹ Though we describe these situations as varying with respect to the need for new disposal arrangements, another interpretation is possible. That is, these three games may describe areas where the need for a new facility is equally acute in all three but where the costs vary. a_1b_1 may describe a situation where both a and b have isolated and suitable land for a landfill. Thus C and X are sufficiently low so that it is worthwhile for each to provide such a facility even if no cooperation is forthcoming. At the other extreme a_3b_3 may describe a situation where there is no available land so that a more expensive facility (e.g. an incinerator) is required.
- ³⁰ Of course, we have considered here only pure strategies. It remains to see whether the introduction of mixed strategies would tend to produce more frequent cooperation.
- ³¹ In one instance I was told of a private hauler who serviced households in both a cooperating and non-cooperating municipality. To exclude him from using the facility would be unfair to persons in the cooperating municipality as their charges might increase if the hauler has to travel a greater distance. At the same time, however, if he is permitted to use the facility persons in the non-cooperating municipality receive free benefits in a reduced charge. Special consideration must be given to this situation. Perhaps a hauler could be permitted to use the facility if a certain percentage of his clients resided within the cooperating municipality.